Recent Rehabilitation Technology for Aging Thermal Power Generation Equipment

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1. Introduction

Having successfully delivered many power generating plants both in Japan and overseas, Fuji Electric is proposing that equipment which has been in service for a long time at aging thermal power plants be rehabilitated completely instead of just being inspected periodically and parts replaced as part of preventive maintenance. Specifically, Fuji Electric proposes such solutions as increasing the efficiency and output capacity of the turbines, implementing remaining life extending countermeasures for critical equipment devices which has deteriorated, making modifications to support changes in fuel conversion and process steam, and so on to meet the needs of our customers.

This paper presents examples of rehabilitation projects for aging thermal power generation equipment that has been implemented recently by Fuji Electric and also describes the maintenance service technology.

2. Recent Rehabilitation Projects

2.1 Rehabilitation of Unit 9 at Mae Moh Power Plant

The Mae Moh Power Plant is located approximately 3 hours by car from Chiang Mai in northern Thailand. The Mae Moh Power Plant was delivered by Fuji Electric and is a coal-fired thermal power plant operated by the Electricity Generating Authority of Thailand (EGAT) and is the largest in Southeast Asia (10 turbines, Units 4 to 13). Figure 1 shows a photo of EGAT's Mae Moh Power Plant, and Table 1 lists the history of turbine deliveries to the Mae Moe Plant.

The recent rehabilitation of Unit 9 is described below.

This turbine has a 3-casing structure configured as a high-pressure/intermediate-pressure/low-pressure turbine. In the rehabilitation project, advanced technology was applied to increase the efficiency, output power (increasing more than 5 MW) and to increase the reliability of the main parts of the low-pressure turbine (low-pressure rotor, low-pressure internal casing, stationary blade ring, diffuser, etc.). Table 2 lists

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Fig.1 Mae Moh Power Plant

Table 1 History of turbine generator deliveries to Mae Moh Power Plant

Unit	Output	Year of operation startup
Units 4 to 7	150 MW × 4 units	1984 to 1985
Units 8 to 13	300 MW × 6 units	1989 to 1994
Total	2,400 MW total (10 units)	

Table 2 Main specifications of Mae Moh Power Plant Unit 9 turbine

	Before modification	After modification
Type	3-casing reheat condensing	
Output	300 MW	Increased to more than 5 MW
Operating method	Constant pressure throttle governing method	
Main steam pressure	161 bar abs	
Main steam temperature	538 °C	
Reheat steam pressure	37.94 bar abs	
Reheat steam temperature	538 °C	
Vacuum	0.0771 bar abs	
Rotational speed	3,000 r/min	

the main specifications of the Unit 9 turbine and Fig. 2 shows a sectional view of the turbine assembly and a diagram of the scope of this modification work.

(1) Use of completely three-dimensional design reaction blade entirely with CAD

As one measure to improve efficiency, row completely three-dimensional design reaction blade was applied for the reaction blades of stages 1 to 4 of the low-pressure turbine blade to be highly efficient and have significantly less profile loss than conventional reaction blades (Fig. 3).

(2) Use of new generation low pressure blades

New generation low pressure blades that were designed using supersonic fluid analysis (3-dimensional time marching method) and provide largely improved performance are used. Lean-radial stationary blades that are curved in the circumferential direction are used as the last stage stationary blades and realize a large improvement in efficiency (Fig. 4).

(3) Use of improved exhaust diffuser

The exhaust diffuser provided to reduce exhaust loss of the low-pressure last stage trailing flow has been replaced, incorporating a new design to enhance the performance of the exhaust diffuser and realize a reduction in exhaust loss.

(4) Use of labyrinth opposing fins

A double-fin type (opposing fin type) that is highly effective in sealing steam is used at the steam seal of the low-pressure blade row to reduce steam leakage loss and improve efficiency (Fig. 5).

(5) Measure to prevent stress corrosion cracking (SCC) in blade root part

The large low-pressure moving blade groove of the low-pressure rotor is processed into a fir tree type root blade shape. In order to decrease the risk of stress corrosion cracking (SCC) by deterioration of the operating environment (steam properties), shot peening (a method in which tiny steel balls are projected onto the rotor surface to forcibly provide compressive residual stress) is performed on the blade groove of the low-pressure rotor to improve resistance to SCC.

Fig.2 Sectional view of the turbine assembly and diagram of scope of renewal work

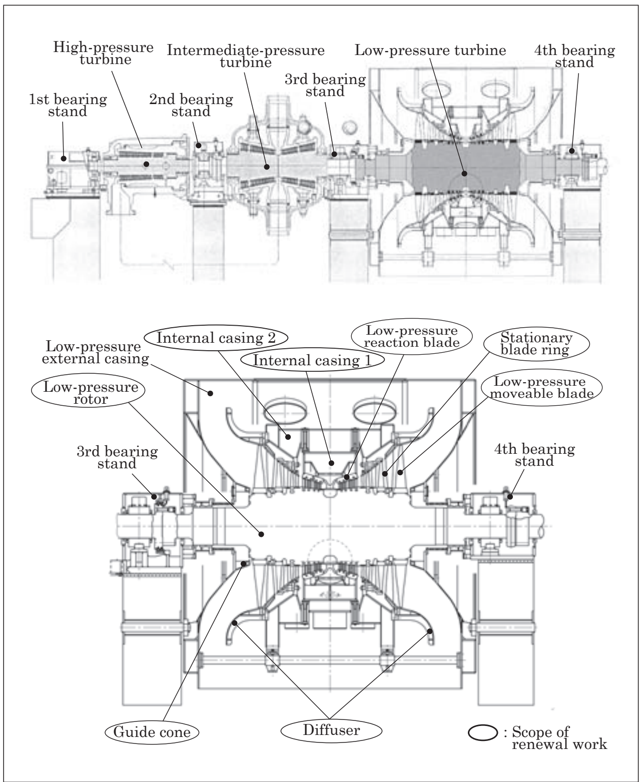


Fig.3 Reaction blades designed entirely with 3-dimensional CAD technology

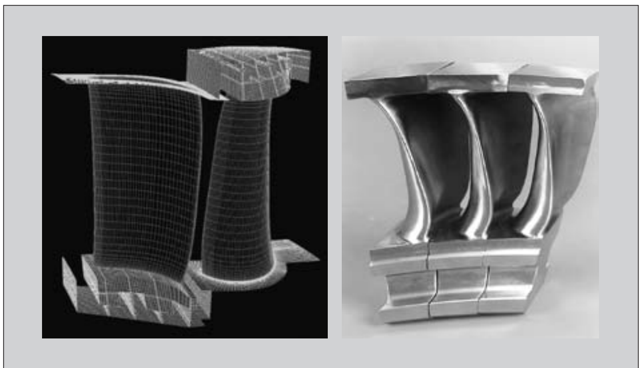


Fig.4 Lean-radial stationary blades

Fig.5 Double fin-type labyrinth

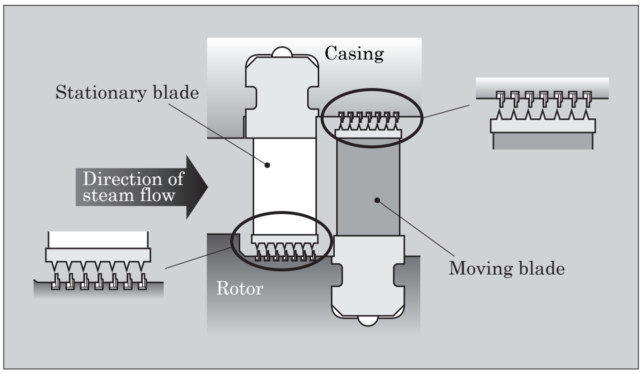
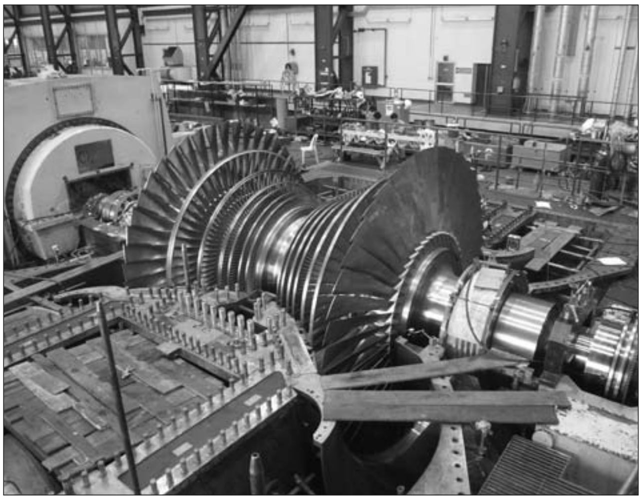


Fig.6 Onsite partially assembled new low-pressure rotor



(6) Use of hydraulic coupling bolts

With the renewal of the low-pressure rotor, all coupling bolts were replaced with hydraulic coupling bolts, enabling modifications to be performed more quickly and reducing the time required for future periodic inspections. Figure 6 shows a new low-pressure rotor in the process of being assembled onsite.

2.2 Rehabilitation of Grand Haven Power Plant

The Grand Haven Power Plant is located on the eastern bank of Lake Michigan in the United States, and is a municipal coal-fired thermal power plant in the city of Grand Haven, Michigan. This thermal power plant facility began operation in 1982 and has been running for more than 20 years, and in this rehabilitation project, the steam turbine unit was modified, and a part of the generator and transformer were replaced in order to increase power output from 73.2 MW to 80 MW. Table 3 and Fig. 7 list main specifications of the turbine for the Grand Haven Power Plant and show a sectional view of the turbine assembly, respectively.

This turbine has a 2-casing structure and is configured from a high/intermediate pressure turbine that combines a high pressure part and a low pressure part, and a low-pressure turbine. The rotor, internal casing, moving/stationary blades, and other such parts have been updated to the latest design, resulting in higher output power and increased efficiency. Figure 8 shows a new high/intermediate pressure internal casing that is in the process of being assembled onsite. The main modifications are as follows.

(a) Reduced throttle loss by using constant pressure throttle governing method
(b) Improved efficiency by using completely three dimensional design reaction blade
(c) Increased cooling capacity of power plant air cooler
(d) Increased cooling capacity of main transformer
(e) Optimization of governor and automatic voltage regulator

Table 3 Main specifications of turbine for Grand Haven Power Plant

	Before modification	After modification
Type	2-casing reheat extraction condensing	
Output	73.2 MW	80 MW
Operating method	Constant pressure nozzle governing method	Constant pressure throttle governing method
Main steam pressure	101 bar abs	
Main steam temperature	538 °C	
Reheat steam pressure	25.6 bar abs	25.0 bar abs
Reheat steam temperature	538 °C	
Vacuum	0.085 bar abs	
Rotating	3,600 r/min	

Fig.7 Sectional view of turbine assembly

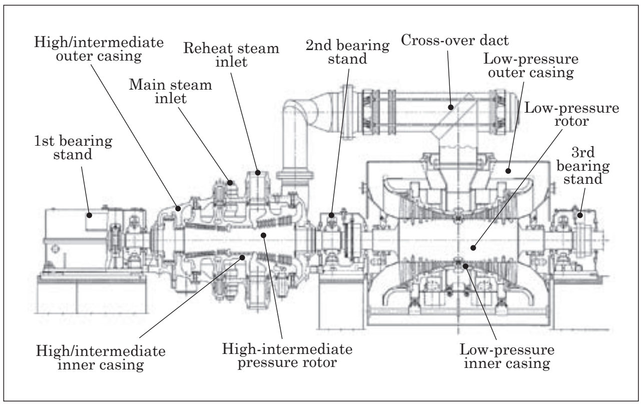


Fig.8 New high/intermediate pressure internal casing partially assembled onsite

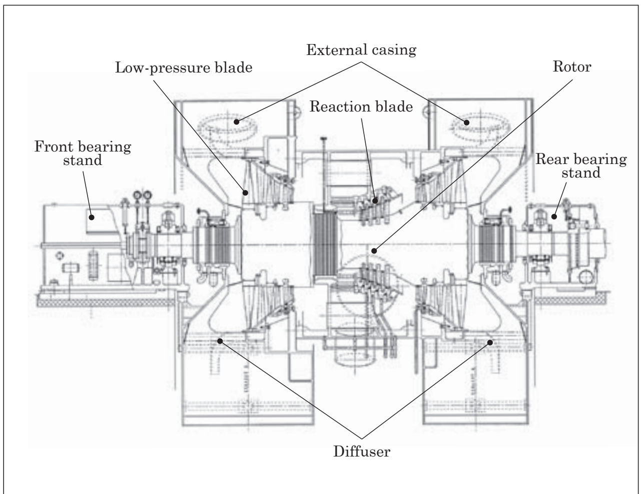
2.3 Rehabilitation of Dixie Valley Geothermal Power Plant

The Dixie Valley Geothermal Power Plant is located approximately 200 km from Reno, Nevada, USA. The steam source properties (pressure, temperature, flow rate, impurities, etc.) for this geothermal power

Table 4 Main specifications of turbine for Dixie Valley Geothermal Power Plant

	Before modification	After modification
Type	Single-casing admission condensing	
Output	60.5MW	64.7MW
Main steam pressure	6.2 bar abs	6.14 bar abs
Main steam temperature	161.7°C	459.4°C
Admission steam pressure	1.43bar abs	1.52bar abs
Admission steam temperature	112.8°C	111.7°C
Vacuum	High-pressure vacuum region 0.055 bar abs, low-pressure vacuum region 0.090 bar abs	
Rotational speed	3,600 r/min	
Blade length of last stage	658 mm	665 mm

Fig.9 Sectional view of turbine assembly



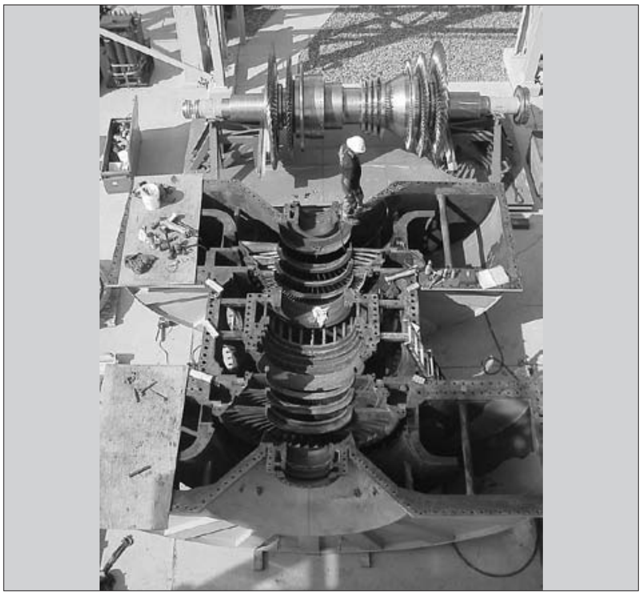
plant have changed with age. This geothermal steam turbine began operation in 1988, and as a result of changes in the steam conditions due to the long-term operation, a decrease in turbine efficiency was observed and optimization of the power generating equipment had been required.

In response to such customer needs, in the rehabilitation work, the latest designs were applied to the main components (rotor, moveable/stationary blades, stationary blade ring, diffuser, etc.) of the turbine, the turbine output was increased from 60.5 MW to 64.7 MW, and the turbine efficiency was also increased. Table 4 lists the main specifications of the Dixie Valley Geothermal Power Plant and Fig. 9 shows a sectional view of the turbine assembly.

Figure 10 shows an onsite turbine undergoing modification. The main modifications are as follows.

(a) Improved efficiency by using complectely three dimensional design reaction blade
(b) Improved efficiency by new generation low-pressure blades

Fig.10 Onsite turbine undergoing modification



(c) Improved efficiency by improved exhaust diffuser
(d) Optimization of automatic voltage regulator

3. Fuji Electric's Maintenance Service

(1) Leak buster

In a condensing-type turbine, the turbine exhaust pressure is a vacuum, but if there is an increase in leakage of external air into the vacuum region, the degree of vacuum will deteriorate and performance will decrease, leading to increased fuel costs and the corrosion of devices. The leak buster is a service that detects air leaks in the vacuum region, uses helium gas to identify the leak locations accurately, and then quantitatively computers the amount of leakage.

The leak buster specifies leak locations and leakage amounts with significantly more accurate than the various leakage detection methods employed in the past. The leak buster has been used in equipment in Japan, but has also recently been used with turbines delivered overseas and with turbines made by other manufacturers, and has met customer expectations.

(2) Hybrid gas extraction system

Geothermal power plants use natural steam to generate electric power. This steam, however, often contains 1 to 8% (weight percentage) of non-condensable gases such as carbon dioxide gas, hydrogen sulfide gas and so on.

In the case of a condensing steam turbine plant, these non-condensable gases must be extracted from a condenser, and larger-capacity gas extraction system is required than in the case of a typical thermal power plant.

Gas extraction system usually employs a steam ejector system or gas compressor system. The steam ejector method does not involve a rotating parts and is therefore maintenance-free, but its efficiency is poor and requires a large amount of driving steam. In order to improve efficiency at existing plants that use the steam ejector system, replacement with a hybrid system combining a vacuum pump is proposed. The hybrid system combines a first-stage ejector and a second-stage vacuum pump (Fig. 11). The use of a vacuum pump reduces the amount of ejector drive steam, and increases the turbine output with the surplus steam, and even if the ejector drive steam amount is deducted, the net generation line output can be increased dramatically. These improvements increase efficiency the more at plants where there is the higher percentage of non-condensable gases.

(3) Phased array inspection

As turbines become larger in size, the turbine low pressure blades are being made longer. In order to ensure the soundness of the root part of a blade, MT (magnetic particle testing) had previously been performed on the root parts of low-pressure moveable blades during periodic inspections in which the turbine casing is opened up. As a technology for inspecting the moveable blades without having to remove them, phased array ultrasonic testing is recently being performed onsite. Figure 12 shows the phased array inspection of a fir tree type root of a low-pressure moveable blade.

Fig.11 Hybrid gas extraction equipment

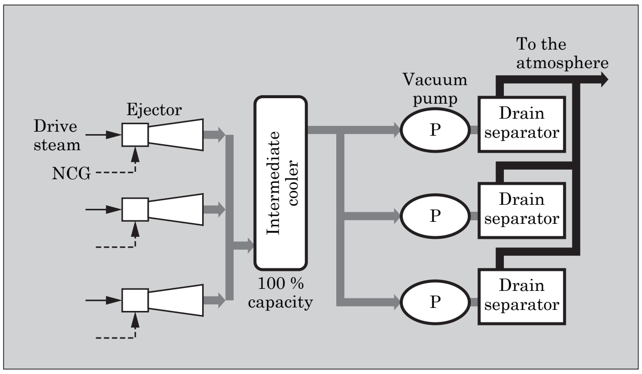
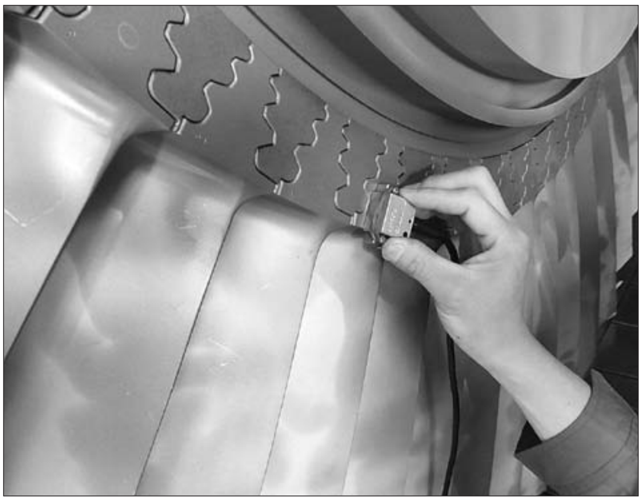


Fig.12 Phased array inspection of fir tree type root of low-pressure moveable blade



(4) Turbine residual life evaluation service

Since developing turbine residual life evaluation technology in 1987, Fuji Electric has performed approximately 50 residual life evaluations and had these valuable data. Inspection methods suitable for the structure and characteristics of each device are optimally combined to conduct highly reliable residual life evaluations, and advices regarding device replacement and repair are provided.

Residual life evaluations have focused mainly on turbines in Japan, but recently, residual life evaluation service is also being provided to aging thermal power plant equipment that has been delivered overseas.

(5) Patrol QC (quality control) assessment service

For overseas thermal power plant equipment, preventive maintenance is sometimes inconsistent, and periodic inspections that involve opening the turbine casing are often not performed. Symptoms of trouble due to long-term operation are often overlooked.

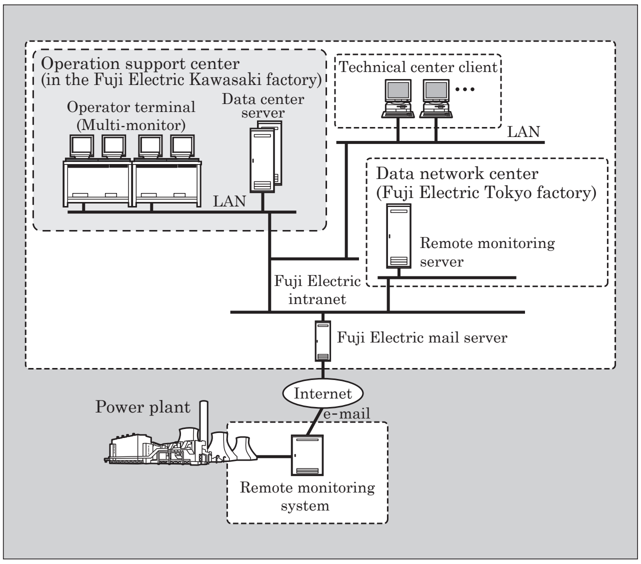
Under these circumstances, since 2002, Fuji Electric has been providing a QC assessment service centered on the Taiwanese region, and based on the assessment results has proposed periodic inspections by opening the turbine casing and preventative maintenance to prevent trouble from occurring and increase the reliability of the equipment.

Future plans call for the patrol QC assessment service to be expanded to the Asian region to meet customer needs.

(6) Operation support center

With the increase in thermal power plant equipment delivered overseas, Fuji Electric has developed and introduced a remote monitoring system (RMS) as a support service for our customers, and sampled data from the power plant and the control system status can be monitored remotely from the operation support center. With the operation support center, not only

Fig.13 System configuration



can long-term operation data be acquired, but services ranging from daily operational support to error diagnosis performance evaluations, proposals of preventative and predictive maintenance, and so on are provided.

Judgments based on the relative and trend monitoring of the operation data enable abnormalities in the power generating equipment to be predicted, and provision of guidance for required countermeasures to customers help prevent accidents. Moreover, if an accident were to occur, this data can be supported to identify the cause of the accident or provide support for recovery rapidly, thereby increasing customer satisfaction (CS).

With the operation support center, the use of a power plant facility information total management system (POP-FIT) enables databases of equipment specifications, design drawings, user manuals, recorded inspections, equipment history, and the like to be accessed, and the appropriate support provided quickly. Figure 13 shows the system configuration of a remote monitoring system.

4. Postscript

Examples of Fuji Electric's recently implemented rehabilitation of an aging thermal power plant facility and maintenance services have been presented.

As the number of aging thermal power facilities increases in the future, Fuji Electric intends to continue to provide optimal rehabilitation plans and maintenance services as solutions that meet customer needs.