RENOVATION AND MODERNIZATION
IN AURAIYA GAS POWER STATION

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ABSTRACT:

In general, power plants are planned to be operated for the term which is decided by the customer. However, the plants may need to be operated for a term exceeding the initial plan depending on changes in environment surrounding the plants such as an extension of a contract for fuel supply, delay in construction of new plant and so on. Under such circumstances, it is possible to extend the lifetime by applying proper assessment and maintenance. MHPS can provide a proposal of plant restoration program for rehabilitation aimed at extending the plant lifetime including recovery of the performance.

Auraiya Gas Power Station, a combined cycle plant consisting of four M701D gas turbines in total and two steam turbines (2 on 1, 2 Blocks), started operation in 1989. It has been in service for more than 25 years with reliable and successful operation and almost reached approx. 180,000 operating hours in the leading unit. "Renovation & Modernization (R&M)" program for Auraiya Gas Power Station was established in order to extend the plant lifetime and recover the performance up to original Name Plate Capacity based on the discussion between NTPC and MHPS. The R&M program had been completed for all 4GTs safely, promptly, and economically in 2014 and 2015.

After the application of R&M program, the situation surrounding Auraiya Gas Power Station has been changing and the plant is now being forced to shutdown and start up much more frequently due to shortage of fuel gas supply amount. MHPS would like to promote various proposals such as condition-based maintenance, further performance improvement, NOx improvement, reliability enhancement of gas turbines, improvement of operational flexibility in order that the customer can maximize their profit.

This document describes the above experience of R&M program and future proposal for Auraiya Gas Power Station considering the recent situation surrounding the plant.
1. Introduction

Auraiya Gas Power Station started commercial operation in 1989 as a large capacity combined cycle power station. The power station consists of 2 Blocks of 2 on 1 shaft (four M701D gas turbines and two steam turbines) and gross power output is 663.36 MW. It has contributed to stable power supply to Uttar Pradesh for a long time.

The power station has been in service for more than 25 years. The unit which has the longest operation history has been operated for more than 180,000hrs and the plant faced performance degradation of gas turbines due to long term operation and unstable operation due to production stoppage for an aged control device. To resolve them, Renovation and Modernization (R&M) work had been conducted in 2014 and 2015. We would like to introduce the details of the work.

Auraiya Gas Power Station has been changing and the plant is now being forced to shut down and start up their gas turbines much more frequently due to shortage of fuel gas supply amount. Under such circumstances, we would also like to introduce our efforts to maximize the customer’s advantage.

2. Purpose of Renovation and Modernization in Auraiya Gas Power Station

In general, power plants are planned to be operated for the term which the customer decided and it is possible to extend the plant lifetime by applying maintenance. MHPS can provide a proposal of Plant Restoration Program for rehabilitation aimed at extending the plant lifetime based on the discussion with customers.

The benefits of plant restoration program are to increase their plant operating reliability by applying MHPS technical recommendations based on the operation experience and the findings and also to recover the degraded condition in order to keep or improve their competitiveness in the market.

Figure 1: Lifetime extension for plant

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In 2014 and 2015, NTPC and MHPS had conducted R&M work for major equipment in the plant, gas turbines and their auxiliaries for the following purposes.

- Recovery of gas turbine power output up to the original Name Plate Capacity
- Extension of plant life by 10 years
- Modernization of control device

3. Power Output Recovery by R&M Work and the Measures

Power output by gas turbines in Auraiya Gas Power Station had been remarkably degraded due to 25-year operation. MHPS aimed to recover the output to Name Plate Capacity by R&M work through the following processes.

**Step-1**

- Output degradation amount by 25-year operation was measured and evaluated. In addition, actual gas turbines were inspected when needed. Measures to recover the output to Name Plate Capacity were studied based on those results.

**Step-2**

- Only the renovation of components such as combustor, turbine blade and turbine vane is not enough to keep the original gross power output because deterioration of other components is also inevitable. Taking an example, compressor blade tip clearance has influence on gas turbine performance. Since casing is usually deformed after long term operation, it becomes more difficult to maintain proper clearances between moving and stationary parts.
- On the other hand, seal performance such as that in compressor diaphragms area, torque tube area, turbine blade ring area and so on has been also deteriorated, so that they have other negative impacts on gas turbine performance.
- Replacement of GT major components and repair work which were estimated to be needed for output recovery as the result of the study in Step-1 were conducted during R&M work.

**Step-3**

- Upgrade components which are capable of operation under higher TIT (Turbine Inlet Temperature) more than TIT at peak load operation were applied for R&M program. They enable considerable recovery of degraded power output with the operation of higher TIT.
- As only component replacement and repair work in Step-2 could not recover the abovementioned non-recoverable deterioration completely, power output degradation which is equivalent to non-recoverable deterioration was recovered by increase in TIT.
(1) Replacement of GT components and repair work

GT long term operation leads to aging deterioration of GT inner components such as compressor diaphragms area, torque tube area, turbine blade ring area and so on, that is, increase in clearances, deterioration of seal performance. And they finally induce performance degradation of gas turbines.

Deteriorated GT major components shown in Table 1 and Figure 3 were replaced with new ones or refurbished ones during R&M work to make them close to new and clean condition as much as possible.

Table 1: Scope of component replacement during R&M work

<table>
<thead>
<tr>
<th>Component Category</th>
<th>GT#1</th>
<th>GT#2-GT#4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor Components</td>
<td>New</td>
<td>Refurbishment</td>
</tr>
<tr>
<td>Combustor Components</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>Turbine Components</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>Others (Torque tube cover etc.)</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>GT Auxiliaries</td>
<td>Overhaul</td>
<td>Overhaul</td>
</tr>
</tbody>
</table>

Figure 3: Replaced GT major components during R&M work
(2) Coating of compressor blade and diaphragm

The gas turbine compressor section is subject to particles that were not removed by the inlet filters. As one of the performance improvement menus, coating and/or recoating were applied on compressor blades, compressor diaphragms and IGVs to improve their surface roughness, corrosion resistance, erosion resistance, and fouling resistance.

In R&M work, 1 set of new parts of compressor components was supplied and installed in the first unit, repair and recoating were performed for IGV, compressor blades and diaphragms rolled out from the first unit. The refurbished components were rolled in second unit. The process was repeated for the third and fourth units.

For recoating of compressor blades and IGV, the method of on-site coating was implemented to shorten the turnaround time by omitting the transportation to and from a coating facility. The mobile workshop shown in Figure 4 was brought in the site and recoat was implemented.

![Figure 4: On-site coating for compressor blades and IGV](image)

(3) Increase of turbine inlet temperature by the application of upgraded hot parts

Upgraded components shown in Table 2 are provided to enhance the durability for R&M work. These parts which are capable of operation under higher TIT at peak load operation and above have been applied to gas turbines in Auraiya Gas Power Station.

The output measurement of gas turbine conducted before R&M work showed the result that the output up to the Name Plate Capacity is difficult only with the replacement and repair of internal major components due to non-recoverable deterioration of gas turbine.

Therefore, to recover the output degradation which cannot be covered by these parts replacement, the output recover was attempted by increasing TIT with the upgraded parts.

As for capacity of downstream equipment of gas turbine, since increased TIT by application of R&M program was within peak load operation of original setting, it was not influenced by limitation
of downstream equipment capacity.

Table 2: Feature of upgraded components for R&M

<table>
<thead>
<tr>
<th>Parts</th>
<th>Feature of Upgraded Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Nozzle</td>
<td>Structure change</td>
</tr>
<tr>
<td>Combustor Basket</td>
<td>Cooling enhancement</td>
</tr>
<tr>
<td>Transition Piece</td>
<td>Cooling enhancement and additional coating</td>
</tr>
<tr>
<td>Turbine Vanes</td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>Cooling enhancement and additional coating</td>
</tr>
<tr>
<td>Row 2</td>
<td>Cooling enhancement and additional coating</td>
</tr>
<tr>
<td>Row 3</td>
<td>Cooling enhancement</td>
</tr>
<tr>
<td>Row 4</td>
<td>Enhanced material</td>
</tr>
<tr>
<td>Turbine Blades</td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>Enhanced material and improved coating</td>
</tr>
<tr>
<td>Row 2</td>
<td>Additional coating</td>
</tr>
<tr>
<td>Row 3</td>
<td>No change</td>
</tr>
<tr>
<td>Row 4</td>
<td>No change</td>
</tr>
</tbody>
</table>

4. Result of R&M work

(1) Implementation schedule

R&M work was implemented for 4 gas turbines at Auraiya Gas Power Station from May 2014 to February 2015. R&M work was conducted by utilizing a spare rotor and replacing major parts in Roll-in/Roll-out manner as shown in Figure 5. Customer and MHPS completed R&M work of all 4GTs within 10 months, safety, promptly, and economically.
(2) Performance test result

To the upgraded parts which are capable of operation under higher TIT were applied. The performance guarantee test was conducted at the plant and the improved value was evaluated by comparing GT output before and after R&M work.

The result of performance guarantee test after R&M is shown in Figure 6. It was confirmed that all GTs achieved an output exceeding the Name Plate Capacity. As shown in Figure 7, the detail of the output recovery in GT#1 indicated the increase of TIT, turbine efficiency improvement, compressor efficiency improvement and improvement by the increased inlet flow.

Figure 6: Performance test result before and after R&M work

![Figure 6: Performance test result before and after R&M work](image)

Figure 7: GT#1 output analysis after R&M work

![Figure 7: GT#1 output analysis after R&M work](image)

5. Modernization of Control Device

Operating condition of control device was unstable due to the operation over 25-years which designed electronic components life. A control device was modified from MEGAC to Netmation at
the same time as the GT R&M works as shown in Figure 8.

Reasons of modification to Netmation are;
- Damage and breakage due to operation over 25-years which designed electronic components life
- Inability of recovery from damage due to production stoppage of MEGAC parts

Benefits of modification to Netmation from MEGAC are;
- Service support and parts supply for more than 15 years
- Securement of parts supply
- Rapid and comprehensive technical support
- Enhancement of GT control reliability
- Simplified maintenance
- Easy to obtain operation information for the plant

Figure 8: Modification of control device from MEGAC to Netmation

6. Further Proposal after R&M work

After the application of R&M program, the situation surrounding Auraiya Gas Power Station has been changing and the plant is now being forced to shut down and start up their gas turbines much more frequently due to shortage of fuel gas supply amount. In order that the customer can
maximize their profit according to changing situation, MHPS would like to promote various proposals as follows.

(1) Condition based maintenance

Deterioration condition of GT components depends on GT operation load, number of start and stop, specification and composition of fuel, with or without steam and water injection, practices of component maintenance and so on. Component parts may be used for a longer interval more than an original interval depending on the deterioration condition in some cases.

Condition based maintenance is an approach to judge when to conduct inspection by checking deterioration condition of the components by bore scope inspection and crawl through inspection as shown in Figure 9. It can optimize the maintenance cost and maximize the power plant availability.

By developing the above scheme of condition based maintenance, inspection interval has been extended to 12000EOH in other plants.

![Figure 9: Concept of condition based maintenance](image)

(2) Further performance improvement

Since the first M701D gas turbine has been introduced to the market in 1983, MHPS continued to develop new technologies to improve its component design. By upgrading, know-how from high-end classes can be applied to existing gas turbine fleet to increase performance and its operational life.

MHPS can provide further performance improvement package as shown in Figure 10. The upgrade is a program to increase power output by applying the upgraded components with MHPS’s latest technologies i.e. latest cooling structure and enhanced material.
(3) NOx improvement

Steam and water injection facilities are available in Auraiya Gas Power Station to reduce NOx emission. These facilities enable operation of the existing gas turbines under environmental regulation value.

Even if the environmental regulation becomes severer in future, NOx value can be improved with minimum modification to the present combustor and water injection system (with water injection plate) based on our experience without huge modification such as introduction of pre-mix combustor and additional installation of denitrification equipment in Japanese plant.

Water injection plate at the upstream side of fuel gas nozzle flange and additional piping for water supply to fuel gas line are installed as shown in Figure 11.
(4) Reliability Enhancement for Frequent Start Plants

Numerous current markets have reduced operation of gas turbines and many more markets predict a similar future. Reduced operation of gas turbines is primarily a result of an increase in renewable energy. Low cost energy generation becomes capable of providing the market's base load needs which only leaves the peak load available for GTCC. Plants that previously operated at base load are now being forced to shutdown and start up their gas turbines much more frequency.

Auraiya Gas Power Station operated GTs at base load before R&M. However, it has increased number of GT start and stop after R&M due to the shortage of gas amount. Under this situation, MHPS can provide an improvement in the reliability enhancements for frequent start up in order that customers can maximize their profit.

As an example of reliability enhancement for the increased GT start and stop, improvement in feedback system of fuel valve is shown in Figure 12. The feedback system by position transmitter was applied before, however, it will be modified to the feedback system by Linear Variable Differential Transformers (LVDTs) which has higher accuracy and reliability.

The linear movement of a servo actuator's shaft is transmitted in parallel with LVDT's measuring elements (rods and coils). These coils and core do not directly contact with each other. In addition, the guide bushes are coated with lubrication to keep stabilizing their smooth movements. Moreover, this structure is durable and not easily affected by vibrations. As a result, LVDT enable us to measure the movements of servo actuator's shafts with a high degree of accuracy and durability.

In addition to the above, the enhancement against breakage of tenon on compressor diaphragm, wear of turbine disc groove, wear of seal ring housing and breakage of exhaust cylinder can be proposed as the reliability enhancement against the increased gas turbine start and shutdown.

Figure 12: Improved valve feedback system with Linear Variable Differential Transformers (LVDTs)
(5) Reliability Enhancement for Rotor

Recently, fracture of joint bolt between air separator and torque tube was observed during periodical inspection in 2 units of M701D type Gas Turbine (GT) operated for long term (around 150,000 hours). As the results of investigation, it was assumed that the fracture of joint bolt was caused due to SCC (Stress Corrosion Crack).

Hammering test results showed the same damage for the joint bolts on the spare rotor of Auraiya Gas Power Station. Therefore, replacement of all joint bolts for air separator is proposed during CRI for further 10 years operation.

![Fractured joint bolt between air separator and torque tube on rotor](image)

Figure 13: Fractured joint bolt between air separator and torque tube on rotor

(6) Reliability Enhancement for Long Term Shutdown

In the case of GT long term shut down, rust may be generated in Turbine Cooling Air (herein after called the TCA) line. Rust generation increases with the duration of the shut down time and this effect is magnified with relative humidity inside the TCA line. It is important to take some special preventive measures against rust or dust in the gas turbine cooling air system, very especially in high humidity environments. If rust or dust is formed and scattered during operation, high temperature oxidation and/or blade liberation due to clogging of cooling holes may occur in the worst case scenario.

As the result of inspection of TCA line during R&M work, remarkable rust was found inside the TCA filter. Hygroscopic moisture including TCA was condensed during GT shutdown term, and the condensed water may have generated the rust on TCA line. To prevent the rust on TCA line, application of continuous blow using dry air (instrument air) as shown in Figure 14 was recommended.
(7) Reliability Enhancement for Air Intake Filter

Air intake filter is installed on the inlet of gas turbine, and air is sucked after this filter removes dust and dirt in the air. If this filtering is insufficient, it can be a factor causing performance degradation of gas turbine due to fouling on compressor section.

At Auraiya Gas Power Station, compressor section became dirty during short term operation after R&M work. Clearance between filter room and filter element was found at inlet section and outside air may have entered into the GT from the clearance by passing through the filter element.

Modified fixing structure that the filter element is fixed to the filter room by center bolt tightening is introduced. Center bolt tightening prevents the outside air from passing, keeping the compressor section clean. By tightening center bolt of filter and pressing the filter in axial direction, the sealing of filter room and filter shall be increased.
(8) Operational Flexibility

Situation surrounding power plants is always changing due to fuel cost, electricity demand, and construction of new power plants, and the increasing number of renewable sources. MHPS can consider various items for operational flexibility improvement according to requirements from each customer.

Examples of these are described in Figure 17. IGV tracking is a method of closing the IGVs further for higher efficiency during partial load operation. Closing the IGVs further during partial load operation increases the TIT which improves the GTCC efficiency and also reduces CO emissions. The combustion condition becomes more difficult to be controlled so IGV tracking is only applied during stable load condition. This IGV tracking has been already applied to high-end classes gas turbine and its efficiency against the performance improvement at partial load has been confirmed.

![IGV tracking schedule and summary](image)

Figure 17: IGV tracking schedule and summary
7. Conclusion

- Auraiya customer and MHPS completed R&M work for all 4GTs within 10 months in safety, promptly and economically from 2014 to 2015.
- GT output was recovered by more than 9.5% in maximum and exceeded original Name Plate Capacity in all 4GTs.
- R&M program gave continuous reliable operation for more than 100,000EOH operation.
- This rehabilitation plan provides valuable experience to many aging units and will provide important information for other 701D gas turbine fleets coming into this stage.
- MHPS has been continuously updating its organization and service support in order to meet user requirements.
- MHPS’s worldwide fleet is constantly growing with more and more technologically advanced GT models.
- MHPS feedback the proven advanced technology that is gained from the latest models to the rest of its fleet.