Joint research report

Enhancement of Performance and Operation Management of Thermal Power Plants

TOSHIBA

January, 2019
Toshiba Energy Systems & Solutions Corporation
Contents

01 Introduction
(Toshiba Energy Systems & Solutions Corporation)
(Toshiba JSW Power Systems Pvt Ltd)

02 Purpose and Implementation of Joint Research

03 Predictive Detection of Equipment Abnormality

04 Thermal Efficiency Improvement by Performance Management

05 Q&A
Introduction (Toshiba Energy Systems & Solutions Corporation)

Toshiba Corp.

- Toshiba Infrastructure Systems & Solutions Corp.
- Toshiba Electronic Devices & Storage Corp.
- Toshiba Digital Solutions Corp.

Toshiba Energy Systems & Solutions Corporation (10/1/2017-)

- Nuclear Energy Systems & Services Div.
- Thermal & Hydro Power Systems & Services Div.
- Transmission & Distribution Systems Div.
- Energy Aggregation Div.
- New Energy Solutions Project

Toshiba Energy Systems & Solutions Corporation President & CEO

Mamoru Hatazawa (4/1/2018-)

As of 1st Jan, 2018
Introduction
(Toshiba Energy Systems & Solutions Corporation)

President and CEO
Toshiba Energy Systems
& Solutions Corporation

Takao Konishi
Director, Vice President
Thermal & Hydro Power Systems and Services Div.

Kansai Branch Office
Chubu Branch Office
Kyushu Branch Office
Chugoku Branch Office
Hokuriku Branch Office
Tohoku Branch Office
Hokkaido Branch Office
Shikoku Branch Office

As of January 2018

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Introduction
(Toshiba Energy Systems & Solutions Corporation - Products and Systems)

- Toshiba offers products and systems required for various energy sources all around the world.

- Conventional Thermal Power
- Combined-Cycle Power
- CO₂ Capture System
- Power Generation Business
- Geothermal Power
- Hydro Power

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Introduction

No.1 Products & Systems

Power Generation Systems

Thermal Power

*World’s most efficient class C/C system 62% *LHV(Low Heating Values) basis

Coal fired super-critical and ultra super-critical turbines No. 1 share* 53% in Japan

Renewable Energy

Hydro Power

Adjustable-speed pumped storage systems

World’s No. 1 share* 55% *Number of plant basis

Geothermal Power

Geothermal turbines

World’s No. 1 share* 23% *Operating plant capacity basis
Introduction
(Toshiba JSW Power Systems Pvt Ltd (TJPS))

- Establishing an engineering & production network
- between India and Japan

Founded: September 2008 (Chennai Factory was established as Toshiba JSW Turbine and Generator Private Limited (Toshiba JSW), and Gurgaon Engineering Center was established as the thermal power engineering department of Toshiba India Pvt. Ltd. in Aug 2009. Toshiba JSW integrated the engineering department in Jan 2014 and newly started as Toshiba JSW Power Systems (TJPS).)

Location: Gurgaon Engineering Center and Chennai Factory

Ownership: Toshiba Group 75%, JSW Energy 22.52%, JSW Steel 2.48%

Employees: approximately 1,000

Business: Engineering, design, manufacturing, procurement, sales, construction, installation and services for thermal power plants

Capable of managing plant engineering in both conventional & C/C power plant by cooperating with local companies and bases in Japan.

TJPS can work on a global basis and offer various solutions from India to the global market.
Introduction

Toshiba/TJPS making contributions to Indian Energy Sector

- Toshiba JSW
  - UPRVUNL Harduaganj 1x660 MW (Under construction)
    - First Turnkey EPC contract for TJPS in India
  - CGPL Mundra UMPP 5x830 MW (COD: #1 Mar. 2012 - #5 Mar. 2013)
    - First UMPP & 800MW SC Turbine in India
- Toshiba + Toshiba JSW
  - MUNPL Meja 2x660 MW (Under construction)
    - First Bulk Tender utilizing PMP in India
    - One of Most Reliable Plant in India
  - NTPC Darlipali 2x800 MW (Under construction)
- Toshiba JSW
  - NTPC Kudgi 3x800 MW (COD: #1 July 2017, #2 Dec 2017, #3 Sept 2018)
    - First indigenous 800 MW SC turbine
- Toshiba
    - World Record Level Shortest COD by TSB EPC

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Purpose and Implementation of Joint Research

Research Objective

Availability

+ 

Thermal Efficiency

Performance Management System

Research Period: September 22, 2017 to March 26, 2018
Purpose and Implementation of Joint Research

Research Implementation of TPMO
(Thermo-dynamic Performance Monitoring & Optimization)

- Thermal Efficiency
- Create Plant Model
- Identify Performance Deterioration
- Verify Model Results in Actual Conditions
Purpose and Implementation of Joint Research

Research Implementation of EPA (Equipment Predictive Analysis)

1. Availability
2. Collect Operation Data
3. Analyze Operation Data and Create APR Asset Models
4. Configure Systems for Online Monitoring and extract abnormalities

Normal Data
Contents

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Predictive Detection of Equipment Abnormality

Case Study: 20 Events

Troubles by System

- Boiler: 45%
- Emission Control: 15%
- Steam Turbine: 15%
- Electrical: 10%
- GT: 15%

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Predictive Detection of Equipment Abnormality

Results of the Study

- **9 Detectable by APR**
  - (6 Hours) Trip due to high Desulfurization inlet draft
  - (2 Weeks) 3rd HP Heater Leakage
  - (13 Hours) Boiler 2nd Re-heater Tube Leakage
  - (9 Hours) Final SH Damaged
  - (1 Day) AH diff. pressure increase
  - (1 Day) Boiler Limit Operation
  - (12m) GT tripping due to fuel valve issue
  - (16 Hrs) IP turbine by-pass high temperature
  - (37 days) NOX increasing

- **2 Detectable but issue already occurred**
  - Issue already occurred
  - Example: Foreign Object in Mills

- **5 Cannot be detected by APR**
  - Insufficient Data/Instrument
  - Sudden Tripping(Elec)
  - Need more further study

- **4 Excluded from the Analysis**
  - No Data
  - No Sensor
  - Data related in not affect(Piping Leakage)
  - Sudden tripping(Elec)
Event No.1: A High pressure 3rd feed water heater tube leak

Predictive Detection of Equipment Abnormality

Results of the Study

The discovery of the operator is March 17 19:30 hrs
A High Pressure 2 Feed Water Heater Inlet Water Temperature (2 W 0007) Alarm on March 4 at 19:41

Set 14 types of signals in asset
Predictive Detection of Equipment Abnormality

Event No.1: A High pressure 3rd feed water heater tube leak

Detection date: March 4th 19:41
Discovered two weeks ago

March 4 19:41 Abnormal sign detection (A high pressure second feed water heater inlet water temperature threshold lower limit deviation)
March 17th 19:30 Operator Discovery
Event No.1: A High pressure 3\textsuperscript{rd} feed water heater tube leak

Predictive Detection of Equipment Abnormality

3\textsuperscript{rd} Extraction Steam

Lower than expected FW Outlet Temperature

Abrasion thinning/wear leads tube leakage
Predictive Detection of Equipment Abnormality

Results of the Study
Event No.2: Boiler Secondary RH Tube Leakage

Set 17 kinds of signals in asset

Operator discovery is 16: 25 hrs
Can Learn Primary RH Exit Metal Temperature (1BT278) Warning at 3:41 hrs on March 18th
Predictive Detection of Equipment Abnormality

Event No.2: Boiler Secondary RH Tube Leakage

Detection date: February 18 3:41
Discovered 13 hours ago

Detection date: February 18 16:25

3:41 hrs Detection of abnormal symptoms (NO.8 primary RH outlet metal temperature threshold lower limit deviation)
16:25 hrs Operator discovery
Event No.2: Boiler Secondary RH Tube Leakage

Cause of event: The scale in the inner surface of the primary reheater tubes becomes easily peelable by external force, and it peeled off at once at the initial startup after earthquake recovery and it deposited in large quantities on the bend section of RH2 tubes on the downstream side.
Predictive Detection of Equipment Abnormality

Results of the Study
Event No 3: Air preheater differential pressure increase

Set 13 kinds of signals in asset

The discovery by the operator is on August 3 14:36 hrs
Alarm at B - AH secondary air differential pressure (1 DP 013) at 13:38 hrs on August 2
Predictive Detection of Equipment Abnormality

Event No 3: Air preheater differential pressure increase

Detection date: August 2 13:38 hrs
Discovered 1 day ago

Discovery date: August 3 14:36 hrs

August 2 13:38 hrs Abnormal sign detection (B-AH secondary air differential pressure high limit deviation)
August 3 14:36 Operator Discovery
Predictive Detection of Equipment Abnormality

Event No 3: Air preheater differential pressure increase

High dP

Clogged AH Elements
Thermal Efficiency Improvement by Performance Management

Creation of monitoring screen

【Tools · Procedures】

i. Place parts such as graphs and figures

ii. Data acquisition points are assigned
Results of the study

(1) High temperature period (data of 2017/07/21 14:00)

<table>
<thead>
<tr>
<th>A. 補正後実ユニット熱消費率 (Corrected Actual Unit Heat Rate)</th>
<th>6,020.19 kJ/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. 大気温度 Ambient Temperature</td>
<td>22.67 kJ/kWh 0.38%</td>
</tr>
<tr>
<td>C. 大気圧力 Ambient Pressure</td>
<td>0.00 kJ/kWh 0.00%</td>
</tr>
<tr>
<td>D. 相対湿度 Relative Humidity</td>
<td>0.56 kJ/kWh 0.01%</td>
</tr>
<tr>
<td>E. 燃料温度 Fuel Temperature</td>
<td>0.09 kJ/kWh 0.00%</td>
</tr>
<tr>
<td>F. 燃料LHV FUEL LHV</td>
<td>0.0 kJ/kWh 0.00%</td>
</tr>
<tr>
<td>G. 運転時間 Running Hours</td>
<td>27.41 kJ/kWh 0.46%</td>
</tr>
</tbody>
</table>

\[ H = A + (B + C + D + E + F + G) \]

\[ R = H - (I + J + K + L + M + N + O + P + Q + R + S) \]

Heat Rate Deviation

<table>
<thead>
<tr>
<th>H. 実ユニット熱消費率 (Actual Unit Heat Rate)</th>
<th>6,070.91 kJ/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. ガスタービン入口フィルタ差圧 GT Inlet Filter DP</td>
<td>-1.91 kJ/kWh -3.1%</td>
</tr>
<tr>
<td>J. ガスタービン排気差圧 GT Exhaust DP</td>
<td>0.99 kJ/kWh 1.6%</td>
</tr>
<tr>
<td>K. Compressor Efficiency</td>
<td>23.63 kJ/kWh 38.9%</td>
</tr>
<tr>
<td>L. 復水器圧力 Condenser Pressure</td>
<td>3.03 kJ/kWh 5.0%</td>
</tr>
<tr>
<td>M. Main Steam Pressure</td>
<td>2.66 kJ/kWh 4.4%</td>
</tr>
<tr>
<td>N. Main Steam Temperature</td>
<td>-2.73 kJ/kWh -4.5%</td>
</tr>
<tr>
<td>O. Reheat Temperature</td>
<td>5.98 kJ/kWh 9.8%</td>
</tr>
<tr>
<td>P. SH Spray Flow</td>
<td>-6.22 kJ/kWh -10.2%</td>
</tr>
<tr>
<td>Q. RH Spray Flow</td>
<td>-0.52 kJ/kWh -0.9%</td>
</tr>
<tr>
<td>R. Exit Gas Temperature</td>
<td>9.38 kJ/kWh 15.4%</td>
</tr>
<tr>
<td>S. その他説明不可要因 Unaccounted Losses/Gains</td>
<td></td>
</tr>
</tbody>
</table>

Heat Rate Deviation

<table>
<thead>
<tr>
<th>T. 最善達成可能ユニット熱消費率 (Best Achievable Unit Heat Rate)</th>
<th>6,035.80 kJ/kWh</th>
</tr>
</thead>
</table>

When comparing the expected value and the measured value, it was found that there is room for improvement in thermal efficiency of 35.11 kJ / kWh (0.58%).

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When comparing the expected value and the measured value, it was found that there is room for improvement in thermal efficiency of \(35.11 \text{ kJ} / \text{kWh} (0.58\%)\).
Results of the study

② Low temperature period (data of 2017/01/14 10:00)

Comparing the expected value with the measured value, it was found that there is room for improvement in the thermal efficiency of 44.29 kJ / kWh (0.72%)
Comparing the expected value with the measured value, it was found that there is room for improvement in the thermal efficiency of 44.29 kJ / kWh (0.72%)
Thermal Efficiency Improvement by Performance Management

**Summer**

- 35.11 kJ/kWh
- 808 kg/hr CO2

**Winter**

- 44.29 kJ/kWh
- 890 kg/hr CO2

*Based on Chapter 2: Stationary Combustion Table 2.2 “Natural Gas” 2006 IPCC Guidelines for National Greenhouse Gas Inventories-Stationary Combustion in the Energy Industries*