1. Eraring Unit 1-4 Upgrade (Australia)
   1.1 Summary
   1.2 Detailed Scope of Work
   1.3 Field Work
   1.4 Performance

2. Boryeong Unit 1, 2 Plant Upgrade (Korea)
   2.1 Summary
   2.2 Detailed Scope of Work
   2.3 Field Work
   2.4 Performance

3. Sabarmati E&F TPP Upgrade (India)
   3.1 Summary
   3.2 Detailed Scope of Work
   3.3 Field Work

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1.1 Summary of Eraring Unit 1-4 Upgrade (Australia)

**PROJECT OVERVIEW**

**PJT title**
Eraring Unit 1-4 Plant Upgrade

**Client**
Eraring Energy

**Contract year**
2007

**PJT period**
Total 26 months / Unit

**Installation period**
6 months / Unit (installation/commissioning)

**PLANT LOCATION**

Eraring, Australia

**Plant Information**

- **OEM**: BLR: IHI / TBN: Toshiba
- **Plant Type**: Subcritical coal-fired
- **Capacity / COD**: 660MW x 4 Units / 1982
- **Boiler**: Twin steam drum, Natural circulation
- **Turbine**: TC4F – 4 Casings
- **Generator**: Water/Hydrogen cooled type

**Customer Needs**

- Performance upgrade (Output, Efficiency)
- Lifetime extension
- Cyclic operation (Flexibility)

**Scope of Supply**

- Upgrade & replacement of boiler’s S/H, R/H and economizer
- Upgrading steam turbine HIP steam path
  - Replacement of rotor, bucket and diaphragm
  - Replacement of inner shell and journal bearing
  - No. of stages/bucket active length extension
- Generator stator/rotor rewinding

**Customer Benefits**

- Capacity increase: 660MW → 750MW (approx. 13.6% ↑)
- Efficiency increase
  - Boiler and turbine section (approx. 1-3% ↑ per unit)
- Lifetime extension: 20 years or more
- Use of eco-friendly technology
  - Carbon emissions reduction: 865g/kWh – 835g/kWh
1.2 Detailed Scope of Work

1) Overview of Detailed Work Scope for Turbine

- Existing Turbine: TC4F-33.5", 660MW, 158 bar, 538/538

<table>
<thead>
<tr>
<th>Contents</th>
<th>Existing</th>
<th>Upgrade</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Gross Output (MW)</td>
<td>660</td>
<td>750</td>
<td>+90MW (13.6%)</td>
</tr>
<tr>
<td>Throttle Flow (Ton/Hr)</td>
<td>2,016</td>
<td>2,264</td>
<td>+248T/H (12.3%)</td>
</tr>
<tr>
<td>Life Extension</td>
<td>Over 15 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modifications made to improve turbine efficiency to 89% and increase output to 720MW with over-run peaking capacity of 750MW are as follows:

- HP/IP increased stage count and bucket active lengths, smaller root diameter
- HP/IP introduction of advanced bucket, diaphragm and tip seals
- HP/IP advanced bucket root geometries
- HP/IP inner casings, packings and rotors renewed to accommodate changes
- LP section: Packing ring for LP 1-3 stage and gland packing replacement
- Generators re-wound to permit higher power outputs

2) Overall Work Scope of Turbine
1.2 Detailed Scope of Work

3) Overview of Detailed Work Scope for Turbine

- **N1 PKG Head**
  - Existing
  - Upgraded

- **N2 PKG Head**

- **N4 PKG Head**

- **HP Bucket**
  - Existing
  - Upgraded

- **Nozzle Plate**
  - Existing
  - Upgraded

- **IP Bucket**
  - Existing
  - Upgraded

- **HP Inner Casing**

- **Snout Piping**

- **IP Inner Casing**

- **N2 PKG Head**

- **N4 PKG Head**
1.2 Detailed Scope of Work

4.1) Upgraded Design of HP

- Optimized stage count, bucket active length and rotor root diameter
1.2 Detailed Scope of Work

4.2) Upgraded Design of IP

- Optimized stage count, bucket active length and rotor root diameter
1.2 Detailed Scope of Work

5.1) Design Technology – ART (Advanced Reaction Technology)

- Doosan’s ART design improves efficiency by optimizing design fundamentals of steam path including stage count, blade root diameter and blade root reaction.

High Reaction HP Turbine Assembly

Steam Path Optimization

Optimized 3D Flow

ART Blade Feature
5.2) Design Technology – Advanced Anti-Vibration & Tip Seal Technologies

- Doosan leverages its advanced anti-vibration and tip seal technologies for HP and IP steam path designs

Advantages

- Maintenance cost reduction
- Improved tip sealing
- Reduced secondary flow losses
- Suppression of bucket vibration
- Improved startup to minimize rubs
1.3 Field Work

1) Turbine: HP (Inner Casing, Head, Diaphragm, Rotor, etc.)

Old HP & Inner Casing

New HP & Inner Casing

2) Turbine: IP (Inner Casing, Head, Diaphragm, Rotor, etc.)

Old IP & Inner Casing

New IP & Inner Casing
1.3 Field Work

3) Rotor

- New rotors were successfully installed and connected to the Toshiba rotor without a problem
1.4 Performance

1) Operation

Vibration Level

Maximum vibration level was under 50μm

Power Output

2) TBN Efficiency

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guaranteed efficiency</td>
<td>89.22%</td>
<td>89.22%</td>
<td>89.22%</td>
<td>89.22%</td>
</tr>
<tr>
<td>Real efficiency during commissioning</td>
<td>89.85%</td>
<td>90.37%</td>
<td>89.91%</td>
<td>91.38%</td>
</tr>
<tr>
<td>Performance improvement</td>
<td>+0.63%</td>
<td>+1.15%</td>
<td>+0.69%</td>
<td>+2.16%</td>
</tr>
</tbody>
</table>

Average performance improvement

+1.16%
## 2.1 Summary of Boryeong Unit 1, 2 TPP Upgrade (Korea)

### Project Overview

**PJT title**
Boryeong Unit 1, 2 Plant Upgrade

**Client**
KOMIPO ¹)

**Contract year**
2007

**PJT period**
Total 27 months

**Installation period**
3 months / Unit

### Plant Location

Boryeong City, Korea

### Plant Information

<table>
<thead>
<tr>
<th>Plant Information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OEM</strong></td>
<td>BLR: B&amp;W / TBN: Toshiba</td>
</tr>
<tr>
<td><strong>Plant Type</strong></td>
<td>Subcritical coal-fired</td>
</tr>
<tr>
<td><strong>Capacity / COD</strong></td>
<td>516MW x 2 Units / 1983</td>
</tr>
<tr>
<td><strong>Boiler</strong></td>
<td>Steam drum, Natural circulation</td>
</tr>
<tr>
<td><strong>Turbine</strong></td>
<td>TC4F – 3 Casings</td>
</tr>
<tr>
<td><strong>Generator</strong></td>
<td>Water/Hydrogen cooled type</td>
</tr>
</tbody>
</table>

### Customer Needs

- Performance upgrade (Output, Efficiency)
- Lifetime extension

### Scope of Supply

- Replacement of S/H, R/H for the heating surface
- New installation of primary S/H inlet tube, dust economizer, low NOx combustion system
- Upgrading steam turbine HIP steam path
  - Replacement of rotor, bucket, diaphragm, inner shell, etc.
- Generator stator full rewinding with rotor re-insulation

### Customer Benefits

- Capacity increase: 516MW → 553MW (approx. 3.7% ↑)
- Efficiency increase
- Lifetime extension: More than 15 years
- Reduced maintenance cost and coal consumption
- Improved low load operations
- Reducing environmental impacts of emissions

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¹) KOMIPO: Korea Midland Power Co., Ltd.
2.2 Detailed Scope of Work

1) General Features of Turbine
- Existing Turbine: TC4F-33.5", 516MW, 167 bar, 538/538

<table>
<thead>
<tr>
<th>Unit</th>
<th>Existing</th>
<th>Upgraded</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Gross Output (MW)</td>
<td>516</td>
<td>535</td>
<td>+19MW (3.7%)</td>
</tr>
<tr>
<td>Throttle Flow (Ton/Hr)</td>
<td>1,602</td>
<td>1,671</td>
<td>+69 T/H (4.3%)</td>
</tr>
<tr>
<td>Life Extension</td>
<td>Over 15 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Project Milestone
- Total: 27 months (up to C.O.D)

<table>
<thead>
<tr>
<th>Unit: Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>11 12 13 14 15 16 17 18 19 20</td>
</tr>
<tr>
<td>21 22 23 24 25 26 27 28 29 30</td>
</tr>
<tr>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
</tbody>
</table>
2.2 Detailed Scope of Work

3.1) Detailed Work Scope for HP & IP Turbine Parts

- HP & IP Turbine Retrofit: Steam Path Upgrade
2.2 Detailed Scope of Work

3.2) Detailed Work Scope for LP Turbine Parts

- LP Turbine Retrofit & Replacement

- Bearing No.3
- LP L-0 Blades
- LP 1st Nozzles
- LP Nozzle Spill Strips & Packings
- Steam Guide With Water Spray Nozzle
- LP L-0 Nozzles
- LP L-1 Blades
- LP L-1 Nozzles
- LP Nozzle Spill Strips & Packings
- Doosan’s New Blade (Last Stage)
- Doosan’s New Blade (L-1 Stage)

TOSHIWA ROTOR
2.2 Detailed Scope of Work

4) Upgraded Design of HP & IP

- Rotor Design
  - Using Doosan’s Advanced Reaction Technology (ART) for steam path designs
  - Using 3D design tool for optimal stage count and rotor wheel diameter

- Increased stage count
- Smaller wheel diameter
  - HP: 38.5" → 36.5", 2" ↓
  - IP: 44.5" → 38", 6.5" ↓
2.2 Detailed Scope of Work

5) Upgraded Design of the Bucket Dovetail

- Keyed axial entry dovetail has been designed to minimize average and concentrated stresses by increasing the contact area which bears stress

5) Upgraded Design of the Bucket Cover

- Integrated covered bucket has been designed to minimize steam leakage and to avoid bucket vibration during operations
1) Turbine HP & IP Casing Installation

- Two new inner casings and three new packing heads were successfully installed into the existing Toshiba outer casing at a time, without a problem.
2.4 Performance

1) Operation

Vibration Level
- Under 50μm

Power Output
- 536MW

2) Performance

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine cycle heat rate</td>
<td>+0.74%</td>
<td>+0.90%</td>
<td>+0.82%</td>
</tr>
<tr>
<td>Power output increase</td>
<td>+29MW</td>
<td>+31MW</td>
<td>+30MW</td>
</tr>
</tbody>
</table>
# 3.1 Summary of Sabarmati E&F TPP Upgrade (India)

## Plant Information

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEM</td>
<td>BHEL (BLR: Alstom / TBN: Skoda)</td>
</tr>
<tr>
<td>Plant Type</td>
<td>Subcritical coal-fired</td>
</tr>
<tr>
<td>Capacity / COD</td>
<td>110MW x 2 Units / 1984 (#E), 1988 (#F)</td>
</tr>
<tr>
<td>Boiler</td>
<td>Conventional drum type</td>
</tr>
<tr>
<td>Turbine</td>
<td>TC3F – 3 Casings</td>
</tr>
<tr>
<td>Generator</td>
<td>Water/Hydrogen cooled type</td>
</tr>
</tbody>
</table>

## Customer Needs

- Performance upgrade (Output, Efficiency)
- Lifetime extension

## Scope of Supply

- Increasing heating surface by upgrading boiler R/H tube
- Replacement of boiler’s inlet and outlet header
- Upgrading turbine steam path
  - Dismantling internal parts/equipment of existing turbine
  - New HP, IP, LP rotor/bucket and inner casing
- Replacement of generator excitation system and generator overhaul
- Plant C&I upgrade

## Customer Benefits

- Capacity increase: 110MW → 121MW (10% ↑)
- Turbine efficiency increase (approx. 14% ↑ per unit)
- Lifetime extension: 15 years or more
- Availability and reliability improvement
- Reduced maintenance cost and optimized trouble-shooting
- Incorporation of modernized technologies
3.2 Detailed Scope of Work

Scope of Work

- HP, IP and LP Steam Path Upgrade/Replacement (Inner Casing, Diaphragm, Rotor with bucket, etc.)
  - Machining inside of outer casings of HP, IP and LP
  - Retrofit/Replacement of bearing, lube oil systems and packing ring

* The colored parts have been upgraded
3.3 Field Work

**Before Upgrade**

[Images of turbine installation before upgrade]

**After Upgrade**

[Images of turbine installation after upgrade]

**Turbine Installation**