Feasibility Studies with the Aim of Developing a Bilateral Offset Credit Mechanism FY2011

Studies for Project Development and Organization

Program organization research on efficiency enhancement project of coal-fired thermal power plant in the Republic of India

New Energy and Industrial Technology Development Organization (NEDO)
Idemitsu Kosan Co., Ltd.
Mizuho Corporate Bank, Ltd.
Program organization research on efficiency enhancement project of coal-fired thermal power plant in the Republic of India

1. Outline
For the purpose of the reduction of CO₂ emissions in aging thermal power plants in India, combustion optimization, retrofit of Boiler Auxiliary Machinery, turbine rehabilitation and coal cleaning are investigated. In addition, the preliminary calculation of GHG reduction potential associated with the improvements, the proposal of MRV method toward CO₂ reduction, the evaluation of economy of this project are conducted, and the dissemination and deployment of its related technologies are also studied.

2. Technologies

**Coal mine**

- Coal preparation

Coal preparation which leads to ash reduction in high-ash Indian coal contributes efficiency improvement in boiler and Boiler Auxiliary Machinery.

**Optimization of combustion in boiler by combustion simulation and retrofit of air heater and fan.**

- Boiler

- Turbine

With the prospect that existing facilities are reutilized as much as possible, a basic design for the rehabilitation of facilities, in which the various specifications of an existing power plant are organized and new technologies are also included, is made.

3. Site surveyed
NTPC Limited, Vindhyachal STPS  #3 Unit  210MW  started in 1989
The results of site study showed that one of the issues in the boiler was the reduction in boiler efficiency due to increase in water filling amount of spray type attemperator at the 1RH exit. With the aim of reducing the water filling amount, combustion simulation analysis was carried out at operating conditions that could reduce the furnace exit temperature. The results of the analysis showed that operating condition existed by which the average gas temperature at furnace exit could be reduced by 46.6 °C compared to the present operating condition.
## Combustion Simulation Results

The average gas temperature at furnace exit became 1153.4 degree C which was estimated to be 46.6 degree C lower than the present operating condition.

## Efficiency Improvement

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Measurements Occurrence mechanism</th>
<th>Improvement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reheater (RH)</td>
<td>Flue gas temp. reduction ← Reduction of RH spray</td>
<td>1.3% (When RH spray is made 0)</td>
<td>Heat rate</td>
</tr>
<tr>
<td>Air Preheater (APH)</td>
<td>Reduction of leakage</td>
<td>0.24% (leakage 25% to 15% at APH)</td>
<td>Boiler efficiency</td>
</tr>
<tr>
<td>FDF, IDF</td>
<td>Reduction of air flow</td>
<td>FDF 110 kW, IDF 170 kW</td>
<td>Fan power</td>
</tr>
<tr>
<td>Air Preheater (APH)</td>
<td>Using high efficiency elements</td>
<td>0.17%</td>
<td>Boiler efficiency</td>
</tr>
<tr>
<td>Primary Air Fan (PAH)</td>
<td>Hot air system → Cold air system</td>
<td>400 kW</td>
<td>Fan power</td>
</tr>
<tr>
<td>IDF</td>
<td>two-stage axial flow fixed pitch fan → Variable pitch axial flow fans</td>
<td>670～510 kW</td>
<td>Fan power</td>
</tr>
<tr>
<td>Air Preheater (APH)</td>
<td>Temperature reduction at outlet of APH</td>
<td>0.17% (3 degree C reduction)</td>
<td>Boiler efficiency</td>
</tr>
</tbody>
</table>
**Technological study**

**Estimation of Coal Preparation Effect**

**[Location & System Flow]**

- Excavated raw coal
- Raw coal pre-treatment
- Coal washing
- Coal washing plant
- Clean coal
- Tailings
- Large tailings, foreign matter, etc.
- Truck/rail transport
- Coal-fired power station

**[Results]**

- About 1.1 million ton of washing coal is required
- 75% recoverable of 25% ash washing coal

**Estimation of preparation effects at Vindhyachal STPS**

<table>
<thead>
<tr>
<th>Ash content</th>
<th>Raw 34.6% ash</th>
<th>Case1 30% ash</th>
<th>Case2 25% ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Efficiency</td>
<td>35.25%</td>
<td>35.85%</td>
<td>36.60%</td>
</tr>
<tr>
<td>PLF</td>
<td>95.30%</td>
<td>97.30%</td>
<td>99.80%</td>
</tr>
<tr>
<td>Axially consumption</td>
<td>7.50%</td>
<td>7.35%</td>
<td>7.16%</td>
</tr>
<tr>
<td>Net Efficiency</td>
<td>32.61%</td>
<td>33.27%</td>
<td>34.10%</td>
</tr>
<tr>
<td>Effects</td>
<td>-</td>
<td>0.66%</td>
<td>1.49%</td>
</tr>
</tbody>
</table>
Technological study

Retrofit Consideration for Turbine System

[Retrofit Scope]

(1) Turbine:
Upgrade for Turbine Stage Steam Path
Expected enhanced heat rate is relatively larger than 5.3% from the existing.

(2) Governing System:
D-EHC Conversion
Easier maintenance and more excellent controllability.

(3) Generator:
Application of Brushless Hydrogen-cooled Generator with 270 MVA class capability
Prevention from stator coil earth fault and flash-over.
Enhancement on Generator capability.

[Outlook and Expectation]

- Retrofit scope dedicates the existing 210MW units to enhance their efficiency with CO₂ reduction and to improve their availability.
- NTPC are very interested in unit efficiency and availability and they hope to apply the upgrading technology into their units.
- There are similar 60 units in India. Then, the preferable outlook is expected for business scheme using the FS results.
Economical Feasibility

Economics of Energy Efficiency Projects in Coal Preparation, Boiler and Turbine at Existing Coal-fired Power Station

(1) Internal interest rate (IRR) and payback year are evaluated in these projects based on the energy efficiency improvement estimated by this FS technical team. Below table shows the summary results in case of zero CO₂ price.

(2) Economic evaluation for coal washing are implemented at two cases. One is based on the project that coal washing is implemented at coal mining, and another project is at power producer side. The results for the coal washing cases are different largely between these two cases.

(3) In the case that CO₂ credit price is 10 EUR/tCO₂, payback year of the boiler/turbine rehabilitation project is improved by 2~3 yrs.

[Equity IRR & Payback Year]

<table>
<thead>
<tr>
<th></th>
<th>Coal washing (coal mine)</th>
<th>Coal washing (power producer)</th>
<th>Boiler</th>
<th>Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project IRR</td>
<td>36.4 %</td>
<td>1.0 %</td>
<td>14.6 %</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Payback Year</td>
<td>2~3 yrs</td>
<td>17~18 yrs</td>
<td>7~8 yrs</td>
<td>12~13 yrs</td>
</tr>
</tbody>
</table>

Note 1: Income tax is not considered in this evaluation.
Note 2: The figures in coal washing are results in case that residual coal can sell to anyone with a lower price.
MRV for Bilateral Offset Credit Mechanism was constructed based on existing CDM methodology, J-MRV002 and ISO14064 etc.

1. Baseline scenario
Baseline scenario is identified in case of rehabilitation projects developed in India as continuous use of existing coal-fired power station with sub-critical technology.

2. Methodology to estimate GHG emission reduction

\[ ER_y = BE_y - PE_y - LE_y \]

*\( ER_y \): Emission Reductions, \( BE_y \): Baseline Emissions, \( PE_y \): Project Emissions, \( LE_y \): Leakage Emissions

○ Baseline Emissions (\( BE_y \))

Plan 1: Fuel Consumption base

\[ BE_y = \sum \left( PC_{fuel,i,y} \times EF_{fuel,i,y} \times \frac{SHR_{BE}}{SHR_{PE,y}} \times PAT_y \right) \]

\( BE_y \) = Baseline emissions in year y (tCO2/y)
\( PC_{fuel,i,y} \) = Total amount of fuel type i consumed in year y (TJ/y)
\( EF_{fuel,i,y} \) = Emission factor of fuel type i consumed in year y (tCO2/TJ)
\( SHR_{BE} \) = Average Station Heat Rate before project implementation for xx years (kcal/kWh)
\( SHR_{PE,y} \) = Station Heat Rate in year y (kcal/kWh)
\( PAT_y \) = PAT target in year y (%)

Plan 2: Generation base

\[ BE_y = PC_{elec,y} \times EF_{elec,y} \times PAT_y \]

\( BE_y \) = Baseline emissions in year y (tCO2/y)
\( PC_{elec,y} \) = Net power generation in year y (MWh/y)
\( EF_{elec,y} \) = Baseline emission factor (tCO2/MWh)
\( PAT_y \) = PAT target in year y (%)
2. Methodology to estimate GHG emission reduction

\[ ER_y = BE_y - PE_y - LE_y \]

*ER\(_y\): Emission Reductions, BE\(_y\): Baseline Emissions, PE\(_y\): Project Emissions, LE\(_y\): Leakage Emissions

**Project Emissions (PE\(_y\))**

\[ PE_y = \sum_i (PC_{fuel,i,y} \times EF_{fuel,i,y}) \]

- PE\(_y\): Project emissions in year y (tCO2/y)
- PC\(_{fuel,i,y}\): Total amount of fuel type i consumed in year y (TJ/y)
- EF\(_{fuel,i,y}\): Emission factor of fuel type i consumed in year y (tCO2/TJ)

**Leakage Emissions (LE)**

J-MRV002 “Project which improves energy efficiency of equipment” shows that if significant leakage is not expected, it shall not be taken into account in the J-MRV methodology. We basically assume zero leakage emission in this project.
GHG emission reduction by doing energy efficiency measurement was calculated based on the results estimated by this FS technical team. Energy efficiency would totally be improved 3.73% (3.28%) in absolute basis, and GHG emission would be reduced by 214,000 tCO₂/y (189,000 tCO₂/y).

### 3. GHG emission reduction

**[Energy Efficiency Improvement & GHG Emission Reduction]**

<table>
<thead>
<tr>
<th></th>
<th>Energy Efficiency Improvement</th>
<th>GHG Emission Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (NET efficiency)</td>
<td>32.61%</td>
<td>-</td>
</tr>
<tr>
<td>Coal Washing</td>
<td>1.49%</td>
<td>85,500 tCO₂/y</td>
</tr>
<tr>
<td>Boiler</td>
<td>0.85%</td>
<td>48,500 tCO₂/y</td>
</tr>
<tr>
<td>Turbine</td>
<td>1.39% (0.94%)</td>
<td>80,000 tCO₂/y (55,000 tCO₂/y)</td>
</tr>
<tr>
<td>Total Improvement and GHG emission reduction</td>
<td>3.73% (3.28%)</td>
<td>214,000 tCO₂/y (189,000 tCO₂/y)</td>
</tr>
</tbody>
</table>

Note 1: Improvements of energy efficiency are described in absolute value unless otherwise noted.
Note 2: Base energy efficiency (32.61%) means 2,637 kcal/kWh.
Note 3: Energy efficiency improvements were described in case of 5.3% (at the top) and 4% (at the bottom) of relative efficiency improvements by turbine upgrading in ‘Turbine’ and ‘Total’.