Current Status of USC Development in Korea
Contents

- KOSEP Introduction
- Why USC?
- Development Trends
- Design Features
- Operation Problems
- Conclusions
KOSEP Introduction

KOSEP was spun off from KEPCO in 2001 as part of the government’s restructuring plan. Backed by solid fundamentals for the half hundred years since 1961, KOSEP is stepping toward for leaping to the Global Power Leader in the future.
KOSEP Introduction – Overview

Overview of electricity industry in Korea and the position of KOSEP

KEPCO

- Generators
  - KOSEP
  - KOMIPO
  - KOWECO
  - KOSPO
  - KEWESPO
  - KHNP

- IPPs (Independent Power Producers)
- PPA (Power Purchase Agreement)

Market Operator

KEPCO as System Operator
Transmission Distribution

- KPX
- Consumer

PPA
Company Profile

Name
Korea South East Power Co., Ltd.

Foundation Date
April 2, 2001

CEO
Do-Soo, Jang

Headquarter
411 Yongdong-daero Gangnam-gu Seoul

Employees
1,986 Persons

Industry
Power Generation
With a corporate philosophy, KOSEP continues to upgrade processes and improve operations to secure a competitive advantage to become a Global Power Leader in the 21st century.
Organization & Employees

As a leading player in the Korean power industry, KOSEP has a well-structured organization for versatile employees

- Power Generation Dept.
- Construction Dept.

The Personnel of KOSEP

<table>
<thead>
<tr>
<th>Executives</th>
<th>Employees</th>
<th>Etc</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1,798</td>
<td>184</td>
<td>1,986</td>
</tr>
</tbody>
</table>

Power Plants
- Samcheonpo Thermal
- Yeongheung Thermal
- Yeongdong Thermal
- Yeosu Thermal
- Bundang Combined Cycle
- Muju Pumped Storage
- Yaecheon Pumped Storage(Under construction)
KOSEP - Facilities

KOSEP is the largest Genco has base-load capacity 6,580 MW and has the attractive site among the thermal Gencos in Korea.

<table>
<thead>
<tr>
<th>Location</th>
<th>“Operation Units”</th>
<th>“Fuel Type”</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samcheonpo</td>
<td>6</td>
<td>Bituminous</td>
<td>3,240</td>
</tr>
<tr>
<td>Yeongheung</td>
<td>4</td>
<td>Bituminous</td>
<td>3,340</td>
</tr>
<tr>
<td>Bundang</td>
<td>10</td>
<td>LNG</td>
<td>900</td>
</tr>
<tr>
<td>Yeosu</td>
<td>2</td>
<td>Oil</td>
<td>529</td>
</tr>
<tr>
<td>Yeongdong</td>
<td>2</td>
<td>Anthracite</td>
<td>325</td>
</tr>
<tr>
<td>Muju</td>
<td>2</td>
<td>Pumped Storage(P/S)</td>
<td>600</td>
</tr>
<tr>
<td>Renewable</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>8,944</strong></td>
</tr>
</tbody>
</table>
Why USC?

Governmental Strategy
New Growth Model for Korea

Fuel (Coal) Consumption
Particular Situation to Import all the coal

Environmental Effect
CO₂ Emission Carbon-tax
Green Growth, The New Growth Model for Korea

‘Low-Carbon, Green Growth’ presented as the national vision by President Lee, Myeong-Bak during his address on August 15, 2008

VISION

To become the World 7th Green Power by 2020, and the 5th by 2050

Three Objectives, Ten Policy Directions

Mitigation of climate change & energy independence
1. Effective mitigation of greenhouse gas emissions
2. Reduction of the use of fossil fuels and the enhancement of energy independence
3. Strengthening the capacity to adapt to climate change

Creating new engines for economic growth
4. Development of green technologies
5. The "greening" of existing industries and promotion of green industries
6. Advancement of industrial structure
7. Engineering a structural basis for the green economy

Improvement in quality of life and enhanced international standing
8. Greening the land, water and building the green transportation infrastructure
9. Bringing green revolution into our daily lives
10. Becoming a role-model for the international community as a green growth leader
Advanced Steam Condition in Thermal Power Plant

- Advanced steam temperature and pressure parameters for USC can deliver the most economical way to improve plant efficiency and operating flexibility, achieve fuel cost saving, and reduce CO₂ emissions for each kWh of electricity generated.
- USC technology is most effective for thermal power plant design to consider the carbon tax.

**Carbon Dioxide Emissions vs Net Plant Efficiency (Based on firing Pittsburgh #8 Coal)**

- **CO₂ Emission, tonne/MWh**
- **Percent CO₂ Reduction from Subcritical PC Plant**

**Break even USC PC total Plant Cost, $/KW**

- **Without Carbon-tax**
- **$7/ton CO₂**
- **$14/ton CO₂**
- **$27/ton CO₂**

30 years, 80% Capacity Factor Sub Critical (Plant cost of $1019/KW, Heat rate of 2305 Kcal/KWh, 37%) USC (Heat rate of 1900 Kcal/KWh, 45%) (EPRI)
Korea imports all the coal from abroad. In recently, low calorie coal imported from Indonesia is increasing for energy price rise.

Bituminous Coal Prices Trend (‘08~‘10, U$/ton)

Coal’s Import Structure of Korea (‘08)

<table>
<thead>
<tr>
<th>Country</th>
<th>Australia</th>
<th>Indonesia</th>
<th>China</th>
<th>Canada</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports</td>
<td>36,369</td>
<td>23,685</td>
<td>14,837</td>
<td>6,521</td>
<td>9,057</td>
</tr>
</tbody>
</table>
Enlarging Uses of Low Calorie Coal

In preparation for coal price rise and competition, the technology development to operate power plant by low calorie coal is expending

Average Heating Value (kcal/kg)

- Samchunpo
- Boryung
- Yeounghung
- Taean
- Hadong
- Dangjin

Average Heating Value (kcal/kg)
KOSEP Introduction
Why USC?
Development Trends
Design Features
Operation Problems
Conclusions
KOSEP has been led UCS technologies by improving steam condition of Yeounghung 3,4 unit at first and plans to lead Korea power industry steadily through the construction of Yeounghung 7,8 unit.
Steam conditions at new plant were reviewed by each maker after considering materials and heat rate. Then we provisionally decided 264kg/cm²/610°C/621°C.

<table>
<thead>
<tr>
<th>Steam Condition</th>
<th>Tandem Compound</th>
<th>Cross Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>246kg/cm²/566°C/593°C</td>
<td>1,773 (Base)</td>
<td>1,801 (Base)</td>
</tr>
<tr>
<td>246kg/cm²/610°C/610°C</td>
<td>1,744 (-1.6%)</td>
<td>1,765 (-2.0%)</td>
</tr>
<tr>
<td>246kg/cm²/621°C/621°C</td>
<td>1,728 (-2.5%)</td>
<td>1,753 (-2.7%)</td>
</tr>
<tr>
<td>264kg/cm²/610°C/621°C</td>
<td>1,722 (-2.9%)</td>
<td>1,747 (-3.0%)</td>
</tr>
<tr>
<td>281kg/cm²/610°C/610°C</td>
<td>1,728 (-2.5%)</td>
<td>1,751 (-2.8%)</td>
</tr>
<tr>
<td>281kg/cm²/621°C/621°C</td>
<td>1,717 (-3.2%)</td>
<td>1,741 (-3.3%)</td>
</tr>
</tbody>
</table>

[Unit: kcal/kWh]

<table>
<thead>
<tr>
<th>Condition</th>
<th>GE</th>
<th>MHI</th>
<th>Hitachi</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam Pressure 35kg/cm²(500psig)↑</td>
<td>0.5%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>-</td>
</tr>
<tr>
<td>Steam Temperature 28°C(50°F)↑</td>
<td>0.7%</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Reheat Stage(1→2)↑</td>
<td>2.0%</td>
<td>1.6%</td>
<td>1.6%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>
Ferritic steels are preferred because of lower coefficient of thermal expansion and higher thermal conductivity compared to austenitic steels. So we are focusing on developing the equivalent ferritic steel capable of operating at metal temperature up to 600 °C.

<table>
<thead>
<tr>
<th>Item</th>
<th>Case 1 246 kg/cm² 566/593°C</th>
<th>Case 2 246 kg/cm² 610/610°C</th>
<th>Case 3 246 kg/cm² 621/621°C</th>
<th>Case 4 264 kg/cm² 610/6210°C</th>
<th>Case 5 281 kg/cm² 610/610°C</th>
<th>Case 6 281 kg/cm² 621/621°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boiler</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom</td>
<td>2.25Cr-1Mo</td>
<td>2.25Cr-1Mo</td>
<td>9Cr-0.5Mo-1.8WVNb</td>
<td>9Cr-1MoVNb</td>
<td>2.25Cr-WVNb</td>
<td>9Cr-1MoVNb</td>
</tr>
<tr>
<td>Top</td>
<td>2.25Cr-1Mo</td>
<td>9Cr-0.5Mo-1.8WVNb</td>
<td>9Cr-0.5Mo-1.8WVNb</td>
<td>9Cr-0.5Mo-1.8WVNb</td>
<td>9Cr-0.5Mo-1.8WVNb</td>
<td>12Cr-MoWVNb</td>
</tr>
<tr>
<td><strong>Final Super Heater</strong></td>
<td>18Cr-8Ni-CuNbN</td>
<td>18Cr-9Ni-CuNbN 18Cr-10NiNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>Superalloy</td>
</tr>
<tr>
<td>Final Reheater</td>
<td>18Cr-8Ni-CuNbN</td>
<td>18Cr-9Ni-CuNbN 18Cr-10NiNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>25Cr-20NiNbN 20Cr-25NiMoNb</td>
<td>Superalloy</td>
</tr>
<tr>
<td><strong>Turbine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotor</td>
<td>12Cr</td>
<td>12Cr</td>
<td>Superalloy</td>
<td>12CrMoWVNbN</td>
<td>12CrMoWVNbN</td>
<td>Superalloy</td>
</tr>
<tr>
<td>Inner Casing</td>
<td>12Cr</td>
<td>12Cr</td>
<td>12CrW 316H</td>
<td>12CrW 316H</td>
<td>12CrW</td>
<td>Superalloy 316H</td>
</tr>
<tr>
<td>Outer Casing</td>
<td>2.25Cr-1Mo</td>
<td>12Cr</td>
<td>12CrW 316H</td>
<td>12CrW 316H</td>
<td>12CrW</td>
<td>12Cr-0.4Mo-2W 12CrW 316H</td>
</tr>
</tbody>
</table>
Analysis about the cost & benefit of greenhouse gas reduction including the carbon tax is proceeding in several different ways.

And respond to the environment regulations actively. We reserve available space for CO₂ reduction equipment for retrofit in the future.

Based on carbon tax($5/ton), The reduction of the cost to consider carbon taxes is as follow

<table>
<thead>
<tr>
<th>Turbine Arrangement</th>
<th>Case1 246kg/cm² 566/593°C</th>
<th>Case2 246kg/cm² 610/610°C</th>
<th>Case3 246kg/cm² 621/621°C</th>
<th>Case4 264kg/cm² 610/610°C</th>
<th>Case5 281kg/cm² 610/610°C</th>
<th>Case7 281kg/cm² 621/621°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tandem Compound</td>
<td>▽12,721</td>
<td>▽19,814</td>
<td>▽22,516</td>
<td>▽19,814</td>
<td>▽24,655</td>
<td></td>
</tr>
<tr>
<td>Cross Compound</td>
<td>△12,271</td>
<td>▽3,490</td>
<td>▽8,781</td>
<td>▽11,483</td>
<td>▽9,682</td>
<td>▽14,072</td>
</tr>
</tbody>
</table>

[Unit : 10,000 Won]
Environmental Facilities

We have installed most advanced environment facilities to aim for the world Best and the most environment-friendly power plant

<table>
<thead>
<tr>
<th>Item</th>
<th>YeongHung #1,2</th>
<th>YeongHung #3,4</th>
<th>YeongHung #5~8</th>
<th>DangJin #9,10</th>
<th>Hekinan #1~3</th>
<th>Hekinan #4,5</th>
<th>Tachibana-wan #1,2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx (ppm)</td>
<td>≤ 55 (≥72%)</td>
<td>≤ 15 (≥90%)</td>
<td>≤ 12 (≥92%)</td>
<td>≤ 50 (≥72%)</td>
<td>≤ 30 (≥80%)</td>
<td>≤ 15 (≥90%)</td>
<td>≤ 45 (≥90%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOx (ppm)</td>
<td>≤ 25 (≥95%)</td>
<td>≤ 20 (≥97%)</td>
<td>≤ 15 (≥97%)</td>
<td>≤ 40 (≥96%)</td>
<td>≤ 28 (≥96%)</td>
<td>≤ 25 (≥97%)</td>
<td>≤ 50 (≥94%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust (mg/S m³)</td>
<td>≤ 20</td>
<td>≤ 5</td>
<td>≤ 5</td>
<td>≤ 5</td>
<td>≤ 5</td>
<td>≤ 5</td>
<td>≤ 10</td>
</tr>
</tbody>
</table>
Coal Blending

In case of new thermal power plant, we plan to co-fire with low calorie coal more than 50% considering impact of boiler materials and supply condition of low calorie coal.

Moreover, we are developing new auxiliary operation systems such as coal blending technology, multi media soot blower, expanding low calorie coal with strong Slagging

<table>
<thead>
<tr>
<th>Power Planet</th>
<th>Design</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>500MW, 800MW</td>
<td>Bit.</td>
<td>Blending Low Calorie Coal(30%)</td>
</tr>
</tbody>
</table>

※ Additional soot blowers are installed because of slagging/fouling caused by low calorie coal blending

<table>
<thead>
<tr>
<th>Power Planet</th>
<th>Coal Type</th>
<th>Max. Sub. Bit. Blending Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young Hung #3,4</td>
<td>Bit + Sub b</td>
<td>50%</td>
</tr>
<tr>
<td>Dang Jin #5,6</td>
<td>Bit + Sub b</td>
<td>30%</td>
</tr>
<tr>
<td>Samchunpo #5,6</td>
<td>Bit + Sub b</td>
<td>70%</td>
</tr>
</tbody>
</table>
Design Features – Steam Generator

- Metal temperature reduction using orifice
- Two Pass type considering heat transfer and cost efficiency
- RH steam temp control by gas damper
- Spiral type water wall tube to minimize temp. deviation
- Furnace design preventing slagging under wide range coal
- Flame stabilization Low Nox burner for low oxygen atmosphere of 2stage OFA
Design Features - Turbine

- Brush seal
- Integral cover bucket
- Large radius root deflector
- Longer last blade bucket
- Advanced vortex stage
- Turbine cooling system
Design Features – Bypass System

- Improvement of Load change characteristics through applying 3 stage feederwater priority control
- RH Bypass system for over 600°C temperature
- Water wall recirculation system considering start-up and cost saving
- HP/LP Bypass system to prevent BLR tubes from overheating and TBN internals from the damage by solid particles
Boiler Tube Damage

○ S/H, R/H Tube Damage

- Main Causes
  - Improper material selection (A213T91)
  - Tube overheating by inside scale (round tube)
  - Welding problem at shop or field (especially different material) and Deterioration

- Counter measures
  - Upgrade tube material at Final S/H and R/H
  - Install Thermo Couple to monitor overheating
  - Minimize welding point of different material

○ BLR Water Wall Tube

- Cause: Due to large Clinker drop
- Solution: Install water cannon

○ BLR ECO Tube Damage

- Due to ash cutting with low-quality coal
**S/H Steam Temperature Control**

**Main Steam Temp Deviation (Left, Right)**

- Left Steam Temp(15~20 °C) > Right Steam Temp
- One pass Boiler < Two pass Boiler
- Full Load < Partial Load
- Cause: Feature of Tangential Corner Firing (Swirl)
- Solution: Install Yawing System + W/B Tilt

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**[Yaw System]**

**[Windbox Tilt]**

[Before]  [After]
Boiler Tube Design Mistake

BLR trips due to Furnace Pr. High

- Slope tube Bundle vs. flat tube bundle
- Generate and build up slag on the slope
- Slag falls to seal trough → Furnace pr fluctuation
- Furnace pr. Hi-Hi Trip
- Cause: Design Error of Tube Bundle shape
- Solution: Install more Soot blowers
KOSEP Introduction

Why USC?

Development Trends

Design Features

Operation Problems

Conclusions
Conclusions

- Korea’s annual energy consumption is expected to increase 2~3% until 2020 by the improvement of living standard.

- To meet these energy demands, it’s necessary to build coal fired power plant (large-scale and USC) along with developing nuclear / renewable energy source.

- The main reason of adoption USC facility is to meet the plant market requirement with considering governmental strategy, environmental effect, economic fuel use and thermal efficiency.

- So, we are developing USC technology to expand low calorie coal use and to keep low electricity-generation cost. And we will see the visible results as the construction of Yeonghung 5,6 unit and Dangjin 9,10 unit after 2015.
Thank You !!!