Development Status of Dynamic Modeling of Taean IGCC Gasifier

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Corporate R&D Institute
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Introduction

Construction Progress of Taean IGCC

- Owner: Korean Western Power
- Capacity: 305 MW (Net)
- Plant Efficiency: 42% (HHV, Net)
- Gasification Efficiency: 80% (HHV)
- Coal Consumption: 2,500 TPD
- Syngas Production: 5,100 TPD
- Plant Construction & Commissioning: 2012 ~ 2015
- Commercial Operation: 2016 ~

(As of 16 April 2015)
Introduction

Key Gasification Equipment Manufacturing & Installation for Taean IGCC

- Gasifier
- Quench Pipe
- Syngas Cooler
- Transfer Duct
Introduction

Study Objectives

✓ To develop dynamic model of Taean IGCC gasifier with commercial software

✓ To predict its operational behavior and deal with its running issues before Taean IGCC’s demonstration and commercial operation

✓ To suggest the plant owner its modified operation and control concept
Control Concept

**Operation Mode**

- **Gasifier Lead Mode**
  - Gasifier Master is on ‘Manual Mode’.
  - Operator Set
  - Case of Load Rejection of Gasification System (while CC Mode)
  - Slow Response

- **GT Lead Mode**
  - GT Master is on ‘Manual Mode’.
  - Operator Set
  - Case of Load Rejection of Combined Cycle (while CC Mode)
  - Rapid Response

- **Coordination Control Mode (CC Mode)**
  - Gasifier Master and GT Master are on ‘Auto Mode’ at the same time.
  - Operator Set
  - Rapid Response
Control Concept

Gasifier Lead Mode (1/2)

CC Module

Set Pressure

MW Error

MW Demand

MW Error

MW Demand

GT Master

Gasifier Master

ASU Master

Syngas Press.
Control Module

* Source: Start-up Conference for the Technical Development of Korean 300MW IGCC Demonstration Plant, Korea Western Power, 2014
Control Concept

Gasifier Lead Mode (2/2)

* Source: Start-up Conference for the Technical Development of Korean 300MW IGCC Demonstration Plant, Korea Western Power, 2014
Dynamic Modeling

Single Flow Diagrams of Gasification Plant

Coal Feeding & Pressurized Unit

Feedstock Input

Coal Burner Unit

Reflection the P&ID Information

Gasifier & Syngas Cooler Unit

Reflection the geometry & design information

Gasifier Module

Reflection the geometry & design information

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Value</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAC</td>
<td>°C</td>
<td>850</td>
<td>°C</td>
<td>Gasification Top Zone Temperature</td>
</tr>
<tr>
<td>P/G</td>
<td>MPa</td>
<td>10</td>
<td>MPa</td>
<td>Pressure Power Gasifier</td>
</tr>
<tr>
<td>G/L</td>
<td>kg/s</td>
<td>5</td>
<td>kg/s</td>
<td>Gasification Mass Flow Rate</td>
</tr>
<tr>
<td>G/S</td>
<td>MW</td>
<td>50</td>
<td>MW</td>
<td>Gasification Power Rating</td>
</tr>
</tbody>
</table>

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Dynamic Modeling

Logic Diagrams of Gasification Plant

Step Sequence Modeling

Functional Loop Diagram Modeling

• Primary Control Loops Modeling
  - KS (Sequence Logic)
  - US (Interlock Logic)
  - UZ (ESD Logic)
### Dynamic Modeling

#### Gasifier Dynamic Modeling

- **Kinetic Reaction and Constant**

<table>
<thead>
<tr>
<th>Reactions</th>
<th>Kinetic Constants</th>
<th>Activation Energy [kJ/kmol]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(s) + 0.5O₂ → CO + CO₂</td>
<td>5.2x10⁴</td>
<td>6.1x10⁴</td>
</tr>
<tr>
<td>C(s) + O₂ → CO₂</td>
<td>5.2x10⁴</td>
<td>6.1x10⁴</td>
</tr>
<tr>
<td>C(s) + H₂O → CO + H₂</td>
<td>7.82x10⁴</td>
<td>1.15x10⁵</td>
</tr>
<tr>
<td>C(s) + CO₂ → 2CO</td>
<td>7.32x10⁴</td>
<td>1.125x10⁵</td>
</tr>
<tr>
<td>C(s) + 2H₂ → CH₄</td>
<td>1.2x10⁻¹</td>
<td>1.49x10⁵</td>
</tr>
<tr>
<td>CO + H₂O ↔ CO₂ + H₂</td>
<td>2.78x10³</td>
<td>1.5x10³</td>
</tr>
<tr>
<td>CO + 0.5O₂ → CO₂</td>
<td>2.2x10¹²</td>
<td>1.67x10⁵</td>
</tr>
<tr>
<td>H₂ + 0.5O₂ → H₂O</td>
<td>5.159x10¹⁵</td>
<td>3.43x10³</td>
</tr>
<tr>
<td>CH₄ + 2O₂ → CO₂ + 2H₂O</td>
<td>3.552x10¹⁴</td>
<td>1.57x10⁴</td>
</tr>
</tbody>
</table>


- **Analysis Procedure**

1. **Start**
2. [Input] Feedstock, Initial Operation Condition
3. **Equilibrium Analysis**
4. **Kinetic Analysis**
5. **Time-based Product Condition**
6. **Time-based Heat Balance Analysis**
7. [Output] Composition, Temperature, Slag Thickness etc., (according to height)
8. **END**
**Modeling Results (1/5)**

**Load-Down Change**

- **O₂ Demand per Burner
  Ramping Rate**

- **F(x)**

- **Fixed Signal**

- **T**

- **BNR 1**<

- **BNR 2**

- **T**

- **1/N**

- **O₂ (Total)**

- **Local Set Value**

---

**Syngas Production Change with Ramping-Down**

![Syngas Production Change](image)

- **Time [Seconds]**

- **Syngas Production [kg/h @ Gasifier Exit]**

  - **3%/min**
  - **4%/min**
  - **5%/min**

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Modeling Results (2/5)

Load-Down Change

**Gasifier Temperature Change with Ramping-Down**

- **3%/min**
- **4%/min**
- **5%/min**

**O₂/Coal Ratio Change with Ramping-Down**

- **3%/min**
- **4%/min**
- **5%/min**
Load-Up Change

- **O₂ Demand per Burner**
- **Ramping Rate**
- **D**
  - **F(x)**
  - **A**
    - **T**
      - **<**
        - **BNR 1**
        - **BNR 2**
      - **<**
      - **1/N**
      - **O₂ (Total)**
      - **Local Set Value**

- **Coal Flow Cal.**
- **New O₂ Flow Cal.**
- **O₂ Flow @ BNR**

---

**Syngas Production Change with Ramping-Up**

- **3%/min**
- **4%/min**
- **5%/min**

**Syngas Production Change [kg/h @ Gasifier Exit]**

**Time [Seconds]**

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Modeling Results (2/5)

- **Load-Up Change**

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**Gasifier Temperature Change with Ramping-Up**

- 3%/min
- 4%/min
- 5%/min

---

**O₂/Coal Ratio Change with Ramping-Up**

- 3%/min
- 4%/min
- 5%/min
Modeling Results (5/5)

**O₂/Coal Ratio Change**

- **O₂/Coal Ratio Change**
  - Heat Duty Bias
  - Manual Signal Operator
  - High & Low Limiter
  - Burner
  - PVI
  - O₂/Coal Ratio Transmitter

**Decrease in O₂/Coal Ratio**

- Syngas Production (kg/h, @Gasifier Exit)
- Gasifier Temp. (℃)
- CO Mole Fraction
- O₂/Coal Ratio
- H₂ Mole Fraction

Time [Seconds]

0 1800 3600
Conclusion & Next Step

- The gasifier dynamic model shows the reasonable operation behaviors according to load change condition.

- The variation of gasifier operating temperature is less than 100°C in the condition of ramping-down with 3 ~ 4% per minute from 100% to 50% load.

- As oxygen flow is dependent on O₂/Coal ratio with limit factor of less than 10% in ramping-up condition, gasifier operating temperature can remain stable.

- The correction factor between O₂/Coal ratio and total oxygen flow has to be applied to the control function in the near commissioning phase.
Acknowledgement

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THANK YOU!

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