SST6000 – steam turbine for future coal-based power generation

Prof Peng Zeying
Shanghai Turbine Plant, China

Michael Wechsung
Siemens AG, Germany

PowerGen-Asia 2011, Kuala Lumpur, Malaysia
Agenda

Shanghai Turbine Plant & Siemens

State of the Art - USC

Next step - Double Reheat

Outlook - 700°C

Summary
Shanghai Turbine Plant - STP

*the world’s biggest steam turbine manufacturer*

- 1953  Shanghai Turbine Plant  founded
- 1981  Westinghouse design and manufacturing license 300MW & 600MW
- 1995  STP and Westinghouse Joint Venture Shanghai Turbine Co., LTD. (68% STP and 32% Westinghouse)
- 1999  Siemens took over Westinghouse → Chinese / German Joint Venture
- 2003  Licensee for several Siemens Steam Turbines in China
Siemens Steam Turbine History
More than 80 Years

1927
Purchase of Thyssen machinery plant in Mülheim

1954
First super critical steam turbo set worldwide

1967
Start delivery of all German nuclear power plants

1970
„Isar 2“ is today the most powerful steam turbo set

1985
3DS technology: Efficiency SPP > 48%

1996
„Isar 2“ is today the most powerful steam turbo set

1996-1998
Merge Westinghouse, Parsons ALSTOM (Industrial turbine)

1996
Official opening of new heavy machinery workshop

2001
„Hafen“ site new office facilities

2004
Official opening of new heavy machinery workshop

2008
Delivery world’s largest ST for NPP Olkiluoto3

2010
Opening expansion of new office building

For internal use only. Copyright © Siemens AG 2008. All rights reserved.
# Product Portfolio

## Steam Turbine Series

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Pressure/Temp</th>
<th>Output MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST-3000</td>
<td>for Combined Cycle Power Plants (CCPP)</td>
<td>max. 177bar/565°C/565°C</td>
<td>90-250 MW</td>
</tr>
<tr>
<td>SST-5000</td>
<td>for sub critical SPP and CCPP (SPP, CCPP)</td>
<td>max. 177bar/600°C/600°C</td>
<td>150-700 MW</td>
</tr>
<tr>
<td>SST-6000</td>
<td>for Steam Power Plants (SPP)</td>
<td>max. 280bar/600°C/610°C</td>
<td>300-1200 MW</td>
</tr>
<tr>
<td>SST-9000</td>
<td>for Nuclear Power Plants (NPP)</td>
<td>max. 80bar/300°C</td>
<td>1500 rpm</td>
</tr>
</tbody>
</table>

**Max. Output:** 90 – 1900 MW (50 Hz and 60 Hz)

*Copyright © Siemens AG 2011. All rights reserved.*
Agenda

- Shanghai Turbine Plant & Siemens
- State of the Art - USC
- Next step - Double Reheat
- Outlook - 700°C
- Summary
SST 6000 series turbine

- Bypass cooling for minimum wall thickness
- Symmetrical casing design for minimum radial clearances
- Advanced sealing technologies
- Barrel type: minimum radial clearances fast thermal loading capability
- High-performance LP blading for different sizes of exhaust area
- Push rod arrangement for reduced axial clearances
- High performance 3DV™ blading
- IP-admission blade ring with integral cooling

Power range: 600..1200 MW
Design Principle → Modular Concept
example: HP Turbine

T, p

main steam conditions

material change

H50         H60         H70

V1          V2          V3          V4

scaling of modules

power output/mass flow

MW
Design Principle → Modular Concept
example: HP Turbine

<table>
<thead>
<tr>
<th>Main Steam</th>
<th>Subcritical</th>
<th>Supercritical</th>
<th>Ultra-Supercritical</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Temp. °C</td>
<td>Variant 1</td>
<td>Variant 2</td>
<td>Variant 3</td>
</tr>
<tr>
<td>- pressure bar</td>
<td>540 170</td>
<td>550 250</td>
<td>565 260</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design principle</th>
<th>Blade Carrier</th>
<th>Inner Casing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor</td>
<td>1-2% Cr</td>
<td>10%Cr</td>
</tr>
<tr>
<td>Blade Carrier/Inner casing</td>
<td>1% Cr</td>
<td>9-10% Cr</td>
</tr>
<tr>
<td>Inlet outer casing</td>
<td>1%Cr</td>
<td>9-10%Cr</td>
</tr>
<tr>
<td>Exhaust outer casing</td>
<td></td>
<td>1%Cr</td>
</tr>
</tbody>
</table>
## USC references

<table>
<thead>
<tr>
<th>Plant</th>
<th>Country</th>
<th>Power output</th>
<th>Main steam</th>
<th>Reheat steam</th>
<th>Commercial operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isogo</td>
<td>Japan</td>
<td>1 x 600 MW</td>
<td>251 bar / 600°C</td>
<td>610°C</td>
<td>2001</td>
</tr>
<tr>
<td>Yuhuan</td>
<td>China</td>
<td>4 x 1000 MW</td>
<td>262 bar / 600°C</td>
<td>600°C</td>
<td>2007</td>
</tr>
<tr>
<td>Wai Gao Qiao 3</td>
<td>China</td>
<td>2 x 1000 MW</td>
<td>270 bar / 600°C</td>
<td>600°C</td>
<td>2008</td>
</tr>
<tr>
<td>Westfalen</td>
<td>Germany</td>
<td>2 x 800 MW</td>
<td>275 bar / 600°C</td>
<td>610°C</td>
<td>2011</td>
</tr>
<tr>
<td>Eemshafen</td>
<td>Netherlands</td>
<td>2 x 800 MW</td>
<td>275 bar / 600°C</td>
<td>610°C</td>
<td>2012</td>
</tr>
<tr>
<td>Lünen</td>
<td>Germany</td>
<td>1 x 800 MW</td>
<td>270 bar / 600°C</td>
<td>610°C</td>
<td>2012</td>
</tr>
<tr>
<td>Mainz</td>
<td>Germany</td>
<td>1 x 800 MW</td>
<td>273 bar / 600°C</td>
<td>610°C</td>
<td>2013</td>
</tr>
</tbody>
</table>
Operating Experience - Isogo, 48000 EOH

Power Output: 600 MWel
Main Steam: 251 bar/600°C
Reheat Steam: 610°C
Condenser: 0.0507 bar
Type of cooling: once through, sea water
Fuel type: hard coal
comm. operation: 2002

martensitic 13% chrome seal strips
Power Output: 1040 MWel
Main Steam: 270 bar/600°C
Reheat Steam: 600°C
Condenser: 0.053/0.042 bar
With Stage Bypass (Overload)
Fuel type: hard coal

Max. proven power output: 1112 MW!
Steam Power Plant Development Roadmap
Covers Double Reheat and 700°C

Steam Cycle Efficiency (net)

- Single reheat
- Double reheat

Ferrites / Martensites
(240 bar, <~620°C)

Nickel Alloys
(350 bar, 700°C)

→ Higher parameter
→ Larger size
→ Improved cycle

Copyright © Siemens AG 2011. All rights reserved.
Energy Sector
Agenda

Shanghai Turbine Plant & Siemens

State of the Art - USC

Next step - Double Reheat

Outlook - 700°C

Summary
1. Danish Customer
   900MW; 50Hz; 590/604/604; Master Cycle

2. Wai Gao Qiao Unit 9
   1350MW; 50Hz; Cross Compound; 600/620/610
   Variants: SRH, DRH & adv. DRH

3. Japanese Customer
   600MW; 60Hz; 600/610/610 (625)
   Variants: SRH, DRH & adv. DRH

4. Siemens Plant concept
   900MW; 50Hz; Design for CCS; 600/610/610
   Variants: SRH, DRH, 1½-RH
1350 MW double-reheat with Siemens components – example WGQ 9

Cross over pipe: 31.2 m

Too long rotor train and challenging generator size → Cross compound

Thrust
Rotor dynamics
Axial expansion
1350 MW double-reheat cross-compound with Siemens components – 1350MW WGQ9

540 t w/o Generator
990 t with Generator

27 m

55.6 m
1350MW DRH
Steam turbine arrangement and systems of 1st train

Weight of turbine deck + turbine train: ~3500 t
1350MW DRH
Steam turbine arrangement and systems of 2\textsuperscript{nd} train

IP turbine 2a
IP turbine 2b
Hydraulic Supply Unit for turbine valves
Lubricating Oil Module
Overall plant efficiency development

Overall plant net efficiency in %

<table>
<thead>
<tr>
<th></th>
<th>Typical CHN 1000 MW unit</th>
<th>State-of-the-art single reheat</th>
<th>DRH 1350 MW at design conditions</th>
<th>DRH 1350 MW with state-of-the-art technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Rate / kJ/kWh</td>
<td>7320</td>
<td>7140</td>
<td>6947</td>
<td>6765</td>
</tr>
<tr>
<td>Station Power Rate</td>
<td>4.5%</td>
<td>3.5%</td>
<td>4.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>93.6%</td>
<td>95.5%</td>
<td>94.0%</td>
<td>95.5%</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>43.5</td>
<td>46.0</td>
<td>46.3</td>
<td>48.8</td>
</tr>
<tr>
<td>Station Power Rate</td>
<td>4.5%</td>
<td>3.5%</td>
<td>4.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Heat Rate / kJ/kWh</td>
<td>7320</td>
<td>7140</td>
<td>6947</td>
<td>6765</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>93.6%</td>
<td>95.5%</td>
<td>94.0%</td>
<td>95.5%</td>
</tr>
</tbody>
</table>

Copyright © Siemens AG 2011. All rights reserved.
Energy Sector
700°C Steam Power Plant
Affected Components

Steam conditions:
700°C / 350 bar
720°C / 70 bar
**700°C Steam Turbine Technology Challenges**

**Requirements**
- Increased temperature and pressure
- Qualification of available **Nickel alloys** for very heavy and thick-walled parts (forgings and castings > 10 tons)

**Drawback**
- Material costs and machining effort (time)

**Development Focus**
- Production procedures (large forgings & castings, welding, machining)
- Material properties for steam environment, thick-walled components
- Non-destructive evaluation
- Blade and seal technologies
- Design concepts, including cooling
700°C Steam Turbine
Development Project Status

- Large Nickel alloy forging and casting demonstrated
- Welding of dissimilar materials (Nickel alloys / steel)
- Machining tests on Nickel alloy performed
- Design concepts available
700°C Steam Turbine
Principle of Construction for HP Turbine Design

Characteristics

- Proven basic concept (Siemens barrel-type)
- Solid rotor shaft
- Welded rotor and inner casing
- Cooled outer casing with full pressure load
- Inner casing with low pressure load at inlet
- Flanged valve attachment

Principle of Construction

- Live Steam
  - 350 bar
  - 700°C
- Cooling Steam
- Weld Seams of different materials
- Ni-based alloys
- Exhaust Steam
- Weld Seams of different materials
- Ni-based alloys
Agenda

Shanghai Turbine Plant & Siemens

State of the Art - USC

Next step - Double Reheat

Outlook - 700°C

Summary
Further increase of efficiency with different technology

Overall plant net efficiency in %

1000 MW SRH with state-of-the-art technology: 46.0%
700 °C SRH: 49.2% 1)
DRH 1350 MW with state-of-the-art technology: 48.8%
700°C DRH: 52.0%

1) 50.1% with open circuit cooling @ North Sea

Copyright © Siemens AG 2011. All rights reserved.
Energy Sector
Steam Turbine Technology

Development – 700°C as ‘final’ step

~ 2010

**State of the art**

- **USC single reheat** (280 bar / 600°C / 620°C) in tandem compound configuration up to 1200 MW power output

~ 2015

**Next step**

- **USC double reheat** (310 bar / 600°C / 610°C / 620°C)
  - Pilot WaiGaoQiao IV in cross compound configuration up to 1350 MW power output

Beyond 2020

**Future step**

- **700°C single reheat** (350 bar / 700°C / 720°C) in tandem compound configuration up to 550 MW power output
  - German pilot project Wilhelmshaven postponed
- **Increase power output of 700°C** (350 bar / ≤ 720°C) in tandem compound configuration to 900+ MW
  - Operational experience of 550 MW mandatory

Since August 1st, the Siemens global R&D hub for SPP steam turbines officially landed in Shanghai.

Key objective:

- Further extend the cooperation between SEC & Siemens to work an that road mape
Thank you for your attention!

Michael Wechsung  
Head of ST Product Strategy  
Siemens Energy

Rheinstr. 100  
45478 Muelheim an der Ruhr  
Phone: +49 (208) 456-3644

E-mail:  
michael.wechsung@siemens.com