Nuclear Power Plant Construction Challenges: An International Perspective

01 June 2011

Dr. Mzubanzi Bismark Tyobeka
Division of Nuclear Power
Outline

• Global Status of NPPs & New Build Efforts
• Global Trends in NPP Construction
• Key considerations and strategies in NPP construction projects
• Case studies and lessons learned
• Conclusions
• Acknowledgements
Current Global Status of Nuclear Power

- 437 nuclear power reactors in operation
  371.5 GW(e)
- 55 nuclear power reactors under construction
- 5 nuclear power reactors in long term shutdown
Number of New Construction Initiation

<table>
<thead>
<tr>
<th>Year</th>
<th>GW</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1.03</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>3.4</td>
<td>4</td>
</tr>
<tr>
<td>2006</td>
<td>3.3</td>
<td>4</td>
</tr>
<tr>
<td>2007</td>
<td>7.6</td>
<td>7</td>
</tr>
<tr>
<td>2008</td>
<td>10.5</td>
<td>10</td>
</tr>
<tr>
<td>2009</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>2010</td>
<td>10.3</td>
<td>9</td>
</tr>
</tbody>
</table>

2010
- Ningde 3 (1000 MW(e), PWR, China) - January
- Taishan 2 (1700 MW(e), PWR-EPR, China) - April
- Leningrad 2-2 (1085 MW(e), PWR-VVER, Russia) - April
- Changjiang 1 (1000 MW(e), PWR, China) - April
- Angra 3 (1245 MW(e), PWR, Brazil) – June
- Ohma (1325 MW(e), ABWR, Japan) May
- Rostov 4 (1011 MW(e), PWR-VVER, Russia) June
- Haiyang 2 (1000 MW(e), PWR-AP1000, China) June
- Fangchenggang 1 (1000 MW(e), PWR, China) July
Construction of NPPs started each year
Typical Construction Schedule for Gen III+ NPPs

Site preparation: 18~24 M
Construction: 36~42 M
Start-up: 6~9 M
Total: 60 M
Since 1972, rapid increase in construction period. Why??
Construction Schedule for Japanese NPPs (e.g. Toshiba)

- Improve Construction Method
- Drawing
- Plastic Model
- 3D-CAD
- 6D-CAD

Nuclear Industry Localization Conference - Cape Town, South Africa - 1 - 3 June 2011
### Construction Schedule at Kashiwazaki-Kariwa Site

<table>
<thead>
<tr>
<th>Unit</th>
<th>Date of C/O</th>
<th>I/F</th>
<th>C/F</th>
<th>C/R</th>
<th>RPV H/T</th>
<th>F/L</th>
<th>C/O</th>
<th>I/F to F/L (I/F to C/O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-1</td>
<td>Sep.18,1985</td>
<td>7M</td>
<td>30M</td>
<td>9M</td>
<td>8M</td>
<td>10M</td>
<td></td>
<td>54 months (64 months)</td>
</tr>
<tr>
<td>K-2</td>
<td>Sep.28,1990</td>
<td>7.5M</td>
<td>26.5M</td>
<td>9M</td>
<td>7M</td>
<td>10M</td>
<td></td>
<td>50 months (60 months)</td>
</tr>
<tr>
<td>K-5</td>
<td>Apr.10, 1990</td>
<td>6M</td>
<td>28M</td>
<td>9M</td>
<td>8M</td>
<td>9M</td>
<td></td>
<td>51 months (60 months)</td>
</tr>
<tr>
<td>K-3</td>
<td>Aug.11,1993</td>
<td>8M</td>
<td>25.5M</td>
<td>7M</td>
<td>7M</td>
<td>10M</td>
<td></td>
<td>47.5 months (57.5 months)</td>
</tr>
<tr>
<td>K-4</td>
<td>Aug.11,1994</td>
<td>8.5M</td>
<td>25M</td>
<td>7M</td>
<td>7M</td>
<td>10M</td>
<td></td>
<td>47.5 months (57.5 months)</td>
</tr>
<tr>
<td>K-6</td>
<td>Nov.7, 1996</td>
<td>6M</td>
<td>21M</td>
<td>6.5M</td>
<td>5.5M</td>
<td>11.5M</td>
<td></td>
<td>40.0 months (51.5 months)</td>
</tr>
<tr>
<td>K-7</td>
<td>Jul.2, 1997</td>
<td>6.5M</td>
<td>22.5M</td>
<td>8.5M</td>
<td>5.5M</td>
<td>8.5M</td>
<td></td>
<td>43.0 months (51.5 months)</td>
</tr>
</tbody>
</table>

I/F: Inspection of Foundation Ground  (* First Concrete: 2 or 3 months later after I/F *)
C/F: Completion of Foundation Mat,  C/R: Completion of Refueling Floor
RPV H/T: RPV Hydrostatic Test,   F/L: Fuel Loading,   C/O: Commercial Operation
Construction Schedule for Korean NPPs

1st: YGN 3&4
2nd: UCN 3&4
3rd: YGN 5&6
4th: UCN 5&6
5th: SKN 1&2
Next: SWN 1&2

First Concrete: 7M, 9M, 7M, 9M, 7M, 6M
COD: 64M, 62M, 58M, 56M, 53M, 47M
Fuel Load: 57M, 53M, 51M, 47M, 46M, 41M

IAEA
## Typical NPP Project Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Y-5</th>
<th>Y-4</th>
<th>Y-3</th>
<th>Y-2</th>
<th>Y-1</th>
<th>Y+1</th>
<th>Y+2</th>
<th>Y+3</th>
<th>Y+4</th>
<th>Y+5</th>
<th>Y+6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milestones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feasibility Study &amp; Project Plan</td>
<td></td>
<td>Major Contract</td>
<td>Excavation</td>
<td>First Concrete</td>
<td>Set RV</td>
<td>COD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feasibility Study</td>
<td>(12)</td>
<td>(18)</td>
<td>(24)</td>
<td>(12)</td>
<td>(18)</td>
<td>(12)</td>
<td>(18)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>License</td>
<td>Prepare PSAR</td>
<td>PSAR Review by Reg. Body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design &amp; Procurement</td>
<td>Long Lead Equip. Order</td>
<td>Equip. Manufacture &amp; Delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>Site Preparation</td>
<td>Excavation</td>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Phase</td>
<td>Pre-Project</td>
<td></td>
<td>Project Implementation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Nuclear Industry Localization Conference - Cape Town, South Africa - 1 - 3 June 2011**
Assumptions to meet 60 months schedule

- **Fundamental Project Assumptions**
  - First-of-a-Kind (FOAK) or Nth of a Kind (NOAK)
  - Labour Resource Availability
  - Cash Flow
  - Labour Shift Structure
  - Reference Location
  - Labour Agreements

- **Site-Specific Assumptions**
  - Site Conditions
  - Seismic Requirements
  - Accessibility/Transportation

- **Engineering & Procurement Assumptions**
  - Engineering
  - Procurement Relationships and Contracts
  - Long-Lead Components
  - Manufacturing Durations

- **Construction Assumptions**
  - Extent of Modular Approach
  - Specialized Equipment
  - Shift of Work Load

- **Licensing and Permitting Assumptions**
  - Licensing Environment
  - Changes in the Licensing Process
Strategies for shortening Con. period

- **Work Efficiency**
  - Early and Detailed engineering before on-site work

- **On-site Work reduction**
  - Modularization with very large crane

- **Work Leveling (Peak Reduction)**
  - Open-top & parallel construction

- **Site Support work efficiency**
  - Site Construction Management support system

Nuclear Industry Localization Conference - Cape Town, South Africa - 1 - 3 June 2011
Manhour Reduction with Early Engineering

Past
- Design Start
- Design/Engineering
- Construction
- Early finish of Engineering

Current
- Design Start
- Design Freeze
- Design/Engineering
- Construction

Detailed engineering completed before construction start

Reduced Site Manpower to 40%
Advanced Construction Methods to Reduce On-site Work e.g - Modularization

- Upper Drywell Module (650 ton)
- RPV (900 ton)
- RCCV Top Slab (550 ton)
- Stator (420 ton)
- RCCV Lower Liner Module (630 ton)
- Upper Condenser Module (270 ton)
- RPV Pedestal Module (410 ton)
- Base Mat Module (460 ton)
- HPU Module (270 ton)
- Lower Condensor Unit (260 ton)
Manpower Peak Reduction Effort
- Construction & Module Experience-

Based on previous ABWR (Conventional Method)

Level-off Manpower Peak

Manpower Distribution

Based on Latest ABWR
Modular Construction

Pros and Cons need to be evaluated based on the job site conditions

<table>
<thead>
<tr>
<th>Good</th>
<th>Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Schedule (If Module is applied to CP)</td>
<td>✗ Increase Engineering for Module</td>
</tr>
<tr>
<td>Reduce Field Work and Leveled On-site Manpower</td>
<td>✗ Increase Temporary Support Structure</td>
</tr>
<tr>
<td>Increase Productivity and Quality under Factory Environment</td>
<td>✗ Early Material Requirements</td>
</tr>
<tr>
<td>More Safely and efficiently at Ground Level Work</td>
<td>✗ Additional Transportation Cost (Large trailer truck, Barge)</td>
</tr>
<tr>
<td>Reusability of PPM Engineering to the Nth Plants</td>
<td>✗ Increase Lifting/Rigging Requirements (Crane, Lifting Jig)</td>
</tr>
<tr>
<td></td>
<td>✗ Inspection of Modular</td>
</tr>
</tbody>
</table>
Construction Schedule with 6D

3D-model + Quantities + Resource + Time = 6D Database

- Develop detailed and precise Construction schedule by construction area based on Quantities and Labor resource
- Simulate the schedule with 3D-model
Integrated Project Management System

Large-scale & Complicated Project Management

Owner

DREAMS(ERP)
- Budget & Cost
- Procurement
- Drawings & Documents
- Quality Management (NCR, CAR)

NPCMS(Site)
- Schedule/Progress Control
- Material Control
- Installation & Inspection
- Startup Information Mgmt.

Contractors

Suppliers (NSSS,T/G,BOP)
- Suppliers’ drawings
- Quality documents

A/E
- Engineering data
- Drawings
- Documents

Constructors
- Drawings & Documents
- Construction info.
- Installation data

Rapid...
Accurate...
Real-time...
Information sharing...

Improvement of Productivity & Efficiency

IAEA

Real-time Enterprise Asset Management System

NPCMS: Nuclear Power plant Construction Management System
Case Studies
Angra 3 Npp in Brazil

Preservation Of Stored Components
Cernavoda NPP, Romania
Right: Unit 1 /2 (in operation), Unit 3 (in preservation)
Left: Unit 4 and 5 (in preservation)
Olkiluoto 3 at the end of April 2009
Source: TVO

<table>
<thead>
<tr>
<th>Core thermal power</th>
<th>4300 MW&lt;sub&gt;th&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net power output</td>
<td>1577 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
<tr>
<td>Net efficiency</td>
<td>37 %</td>
</tr>
</tbody>
</table>

May 2005: First Concrete for Reactor Building
May 2007: RPV installed,
May 2008: Start Hot Functional Tests
Aug. 2008: First Fuel Loading
Nov. 2008: First Criticality
April 2009: Start Demo-Run
Lessons Learned

• Safety requirements must be clearly understood to avoid surprises
  • Understanding regulatory practices is essential as well as regulator’s capacity and resources

• Country-specific circumstances must be understood and taken into consideration

• Vendors and subcontractors have lost knowledge and skills:
  • New competencies are needed for new technologies
  • Need for new subcontractor networks from companies with proven track records to produce qualified sub.cons

• Clear understanding of design standards and codes
Lessons Learned

• Clear understanding of design standards and codes
• Inadequate completion of design and engineering work prior to start of construction can lead to:
  • Delay the full speed construction
  • Continuous pressure to all involved organization
  • Rescheduling manufacturing and construction sequence complicating project management
  • Reduced quality due to time pressure
• Different organizations at different locations – streamlined coordination & communication is vital
Conclusion

- The key to the successful NPP construction lies in careful and detailed construction planning prior to the start of the construction.
IAEA Activities on Construction

• Existing documents

• In the Pipeline
  • Project management during construction of NPPs (being printed)
  • Construction Methods for NPPs – NPTDS (being printed)
  • SRS - Safety Culture during Pre-operation Phase
  • Safety Guide on Construction Activities at Nuclear Installations

• Regional Workshops on Construction Management and Advanced Construction Technologies for NPPs:
  • 19 – 21 August 2010 – The Americas – Charlotte, North Carolina (USA)
  • 22 – 24 June 2011 - Asia Pacific – Shanghai, China
  • 6 – 8 September 2011 – Europe and Africa – Paris, France
Acknowledgements

This presentation material was prepared based on information provided to the IAEA by the following organizations:

- Toshiba, AECL, NPCIL, CNFCC, KHNP, TEPCO, Daewoo Construction, KOPEC, Westinghouse, STUK, MHI and US DoE.