Nuclear Power Plant Construction Challenges: An International Perspective

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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)
- More than 50 nuclear power reactors under construction
- 5 nuclear power reactors in long term shutdown
Number of New Construction Initiation

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

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Construction of NPPs started each year
Typical Construction Schedule for Gen III+ NPPs

<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>
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<tbody>
<tr>
<td>Milestones</td>
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</tr>
<tr>
<td>Feasibility Study &amp; Project Plan</td>
<td>Feasibility Study</td>
<td>(12)</td>
<td>Detailed Site Survey</td>
<td>Environ. Impact Assess</td>
<td>(24)</td>
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</tr>
<tr>
<td>License</td>
<td>Prepare PSAR</td>
<td>(12)</td>
<td>PSAR Review by Reg. Body</td>
<td>(18)</td>
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<tr>
<td>Design &amp; Procurement</td>
<td>Long Lead Equip. Order</td>
<td></td>
<td>Equip. Manufacture &amp; Delivery</td>
<td>(50)</td>
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</tr>
<tr>
<td>Construction</td>
<td>Site Preparation</td>
<td>(18 ~ 24)</td>
<td>Excavation</td>
<td>(12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>60 M</td>
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</tbody>
</table>

Site preparation: 18~24 M
Construction: 36~42 M
Start-up: 6~9 M
Total: 60 M
Average Duration for Past NPP Construction 1969 to 1977 in the USA

Since 1972, rapid increase in construction period
Why ??
USA NPP Construction Experiences
Construction Schedule for Japanese NPPs (e.g. Toshiba)

![Construction Schedule Diagram]

- **Year of Fuel Loading**
  - '70, '75, '80, '85, '90, '95, '00, '05

- **Construction Duration (month)**
  - 40 M, 50 M, 60 M, 70 M, 80 M, 90 M, 100 M, 110 M, 120 M, 130 M

- **Projects**
  - US BWR
  - Japan BWR
  - Japan ABWR

**Key Points**
- Improve Construction Method
- Drawing
- Plastic Model
- 3D-CAD
- 6D-CAD

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## 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 (IF 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>
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<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>6.5M</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, COD 64M, 7M, 57M
- **2nd**: UCN 3&4, COD 62M, 9M, 53M
- **3rd**: YGN 5&6, COD 58M, 7M, 51M
- **4th**: UCN 5&6, COD 56M, 9M, 47M
- **5th**: SKN 1&2, COD 53M, 7M, 46M
- **Next Project**: SWN 1&2, COD 47M, 6M, 41M

**First Concrete**
Typical NPP Project Schedule

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<td>Feasibility Study</td>
<td>Detailed Site Survey</td>
<td>Environ. Impact Assess</td>
<td></td>
<td></td>
<td>Major Contract</td>
<td>Excavation</td>
<td>First Concrete</td>
<td>Set RV</td>
<td>CHT</td>
<td>F/L</td>
</tr>
<tr>
<td>License</td>
<td>Prepare PSAR</td>
<td>PSAR Review by Reg. Body</td>
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<td>Construction</td>
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<tr>
<td>Project Phase</td>
<td>Pre-Project</td>
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<td>Project Implementation</td>
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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
- On-site Work reduction
- Work Leveling (Peak Reduction)
- Site Support work efficiency

Early and Detailed engineering before on-site work
Modularization with very large crane
Open-top & parallel construction
Site Construction Management support system
Manhour Reduction with Early Engineering

- **Past**
  - Design Start
  - Design/Engineering
  - Construction

- **Current**
  - Design Start
  - Design Freeze
  - Early finish of 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 Condenser Unit (260 ton)

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Manpower Peak Reduction Effort
- Construction & Module Experience -

Based on previous ABWR (Conventional Method)

Level-off Manpower Peak

Manpower Distribution

Based on Latest ABWR

Man Power

(month)

Construction Progress
Modular Construction

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

**Good**
- Reduce Schedule (If Module is applied to CP)
- Reduce Field Work and Leveled On-site Manpower
- Increase Productivity and Quality under Factory Environment
- More Safely and efficiently at Ground Level Work
- Reusability of PPM Engineering to the Nth Plants

**Bad**
- Increase Engineering for Module
- Increase Temporary Support Structure
- Early Material Requirements
- Additional Transportation Cost (Large trailer truck, Barge)
- Increase Lifting/Rigging Requirements (Crane, Lifting Jig)
- Inspection of Modular
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

Schedule loaded with Quantities and Resource
Assign Labor resource
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

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* 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
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