Construction Technologies and Management of NPP

Nuclear Power Division
Ki Sig Kang
Nuclear power option included within the national energy strategy

- **Preparation of Infrastructure**
  - Pre project
  - Project decision making
  - Construction

- **Commissioning and Operation**
  - Operation / decommissioning

- **MILESTONE 1**
  - Ready to make a knowledgeable commitment to a nuclear programme

- **MILESTONE 2**
  - Ready to invite bids for the first NPP

- **MILESTONE 3**
  - Ready to commission and operate the first NPP

- **Project Decision Making**
  - Feasibility Study
  - Environment Impact Analysis (EIA)
  - Site Evaluation
  - Bid information Specification
  - Bidding and Evaluation
  - EPC contract

- **Construction**

~ 10 – 15 years

- www.pub.iaea.org/MTCD/publications/ninfrastructure.asp
Structure of the Feasibility Study

• Executive summary

1. Introduction
2. Analysis of electric power supply, justification of new units
3. NPP capacity
4. Site characterization
5. NPP technology options
6. Summary of the results of the preliminary EIA
7. Implementation of the new build project
8. Procurement concept
9. Construction, operation, and human resources
10. Localization
11. Licensing
12. Economic evaluation
13. Financing
14. Public Acceptance
Possible reactor types
Possible reactor types
Construction Status
Current Status of the Nuclear Power Plant

- 439 nuclear power reactors in operation, 374 GW(e)
- 65 nuclear power reactors under construction, 62.9 GW(e), 14 MS

Number of Reactors under Construction Worldwide

<table>
<thead>
<tr>
<th>Country</th>
<th>Reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHINA</td>
<td>27</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>11</td>
</tr>
<tr>
<td>INDIA</td>
<td>5</td>
</tr>
<tr>
<td>KOREA, REPUBLIC OF</td>
<td>5</td>
</tr>
<tr>
<td>EUCHARIA</td>
<td>2</td>
</tr>
<tr>
<td>JAPAN</td>
<td>2</td>
</tr>
<tr>
<td>SLOVAK REPUBLIC</td>
<td>2</td>
</tr>
<tr>
<td>UKRAINE</td>
<td>2</td>
</tr>
<tr>
<td>ARGENTINA</td>
<td>1</td>
</tr>
<tr>
<td>BRAZIL</td>
<td>1</td>
</tr>
<tr>
<td>FINLAND</td>
<td>1</td>
</tr>
<tr>
<td>FRANCE</td>
<td>1</td>
</tr>
<tr>
<td>IRAN, ISLAMIC REPUBLIC OF</td>
<td>1</td>
</tr>
<tr>
<td>PAKISTAN</td>
<td>1</td>
</tr>
<tr>
<td>UNITED STATES OF AMERICA</td>
<td>1</td>
</tr>
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</table>

World Total: 65 reactors of net electrical capacity 62.9 GW(e)

Note: The World Total includes also 2 reactors under construction in Taiwan, China.
Estimation of Nuclear Capacity

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>372</td>
<td>445</td>
<td>511</td>
</tr>
<tr>
<td>High</td>
<td>380</td>
<td>543</td>
<td>807</td>
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</tbody>
</table>

37 % increase
112 % increase
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>14.8</td>
<td>15</td>
</tr>
</tbody>
</table>
Average Duration for Past NPP Construction 1969 to 1977 in USA

Since 1972, rapidly increase construction period Why ??
Construction Schedule of Japan NPPs

- Improve Construction Method
- Drawing, Plastic Model, 3D-CAD, 6D-CAD
### Construction Time Span

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>80</td>
<td>83</td>
<td>6.67</td>
<td>6.92</td>
</tr>
<tr>
<td>Minimum</td>
<td>41</td>
<td>47</td>
<td>3.42</td>
<td>4.08</td>
</tr>
<tr>
<td>1 Quartile</td>
<td>67</td>
<td>61</td>
<td>5.58</td>
<td>5.08</td>
</tr>
<tr>
<td>3 Quartile</td>
<td>105.5</td>
<td>176</td>
<td>8.79</td>
<td>14.67</td>
</tr>
<tr>
<td>Maximum</td>
<td>283</td>
<td>302</td>
<td>23.58</td>
<td>25.17</td>
</tr>
</tbody>
</table>

Resource: Power Reactor Information System in the IAEA database
The Shortest Construction Period

- **Construction Schedule at 1350 Mwe**
  - From F/C to CO: 62 $\rightarrow$ 49 Months

- **Construction Schedule at 1000 Mwe**
  - From F/C to C/O: 64 $\rightarrow$ 47 Months

- C/O: Commercial Operation
- F/C: First concrete pouring
Case Studies
Construction Schedule in Gen III+ NPPs

- **Site preparation**: 12~18 M
- **Construction**: 36~42 M
- **Start-up**: 6~7 M
- **Total**: 60 M

(A) Average Past U.S. Nuclear Schedule (Pre-1977)
- Site Prep: 16mo.
- Construction: 57mo.
- Start Up: 8mo.
- Total: 79 Months

(B) ABWR Proposed Schedule
- Site Prep: 12mo.
- Construction: 36mo.
- Start Up: 7mo.
- Total: 55 Months

(C) ESBWR Proposed Schedule
- Site Prep: 12mo.
- Construction: 42mo.
- Start Up: 6mo.
- Total: 60 Months

(D) ACR-700 Proposed Schedule
- Site Prep: 12mo.
- Construction: 40mo.
- Start Up: 8mo.
- Total: 60 Months

(E) AP1000 Proposed Schedule
- Site Prep: 18mo.
- Construction: 36mo.
- Start Up: 6mo.
- Total: 60 Months
More Safety Requirements

Trabant

New Volvo
Manufacturing High Quality
Professional Staff

high nuclear knowledge, safety culture
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
USA NPPs Construction Experiences

The graph represents the construction experiences of various USA nuclear power plants, with each plant marked on the x-axis. The y-axis indicates the timeline in years. The plants include:

- St. Lucie 2
- Palo Verde 1
- Grand Gulf 1
- Wolf Creek 1
- Seabrook 1
- Summer 1
- Byron 1
- San Onofre 2
- Waterford 3
- LaSalle
- Comanche Peak 1
- Perry 1
- McGuire
- Shoreham 1
- Midland 2
- Catawba 1
- Watts Bar 1
- Harris 1
- Enrico Fermi 2
- Limerick 1

The red line indicates a benchmark or reference point for comparison across these plants.
Bataan Npp in Philippines

Westinghouse 2 Loop
600 Mwe
95% completed,
Political reason
Cernavoda NPP, Romania
Right: Unit 1/2 (in operation), Unit 3 (in preservation)
Left: Unit 4 and 5 (in preservation)
Angra 3 NPP, Brazil
Olkiluoto 3 at the end of April 2009
Source: TVO

<table>
<thead>
<tr>
<th>Core thermal power</th>
<th>4300 MW$_{th}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net power output</td>
<td>1577 MW$_{el}$</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

Electricity Production in 2013
If NPP construction is delayed,

• Increased
  - Financing fee and Interest
  - More oil power plants – Electric cost

- Decreased & Lost
  - Confidentiality from Gov & People
  - Engineers, technicians, workers
  - Equipment, documents
Construction Management
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

With Modularization Method

Milestone:

- S/C
- R/I
- F/C
- M/C
- O/I
- P/S
- RPV
- H/L
- F/L
- C/O

Construction Period = 38M (actual First ABWR)
Manhour Reduction with Early Engineering

**Past**
- Detailed engineering completed before construction start
- Reduced Site Manpower to 40%

**Current**
- Early finish of Engineering

**Graph**
- Manhour Reduction
- Time Axis: '80 '85 '90 '95 '00 '05
- Reduced Site Manpower to 40%
Front-Loaded Construction Engineering

Previous Design Process

- Basic Design
- Detailed Design
- Construction

Front-Loaded Construction Engineering

- Basic Design
- Detailed Design
- Construction

Requirements from Construction Engineering

Inputs from Plant Design (BOQ, Composite Design, etc.)

Source: From Hitachi construction experiences
Construction Schedule with 6D

3D-model linked with Schedule
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
On-site Work Reduction
- Modularization Method -
Manpower Peak Reduction Effort
-Construction & Module Experience-

Level-off Manpower Peak

Based on previous ABWR (Conventional Method)

Manpower Distribution

Based on Latest ABWR
Discussion on Deployment
How can we balance main poles to meet requirements

- Quality
- Risk
- Schedule
- Budget

Project Management
Topics to be issued

- Role and Responsibility of Owner in each stage
  - Feasibility Study
  - Contract type (Turn Key, Split, Component)
  - Bid Evaluation (Technical parts and Generic part)
  - Selection of EPC contractor
  - Selection of Vendor
  - Procurement and Erection
  - Commissioning
- Defence in depth
- Inherent and passive safety features
- Safety design concepts
Two Guidelines under printing

**Construction Management**
- CM - Preparatory Phase
- CM - Construction Phase (after concrete pouring)
- CM - Commissioning Phase
- CM issues and lessons learned

**Construction Technology**
- Open Top Construction using VHL
- Modular Construction
- All Weather Construction
- Steel-Plate Reinforced Structure
When we find an Iceberg

If we simply see the Surface...
When we find an Iceberg

We could be in a Big Problem