Key Activities on Construction Management

October 2012

Ki Sig Kang
Overview of Current Status

- **436** In operation
- **370** GW\(_e\) total net installed capacity
- **63** Under construction
Construction of Nuclear Power

Total Number of Reactors: 62

Country Name

CHINA
RUSSIA
INDIA
KOREA, REPUBLIC OF
JAPAN
PAKISTAN
SLOVAKIA
UKRAINE
ARGENTINA
BRAZIL
FINLAND
FRANCE
UNITED STATES OF AMERICA

Number of Reactors
Number of new Npps construction

![Number of new Npps construction chart]

- **GW**
- **No**

<table>
<thead>
<tr>
<th>Year</th>
<th>GW</th>
<th>No</th>
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<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>15.8</td>
<td>16</td>
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<tr>
<td>2011</td>
<td>1.9</td>
<td>4</td>
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Manpower and Duration

- Manpower: 4000/day, more than 80 Months
- Preparation: 40% and Implementation: 60%
Material & Cost

- Rebar (Ton) = 76,070
- Cable (Km) = about 4,000
- Instrumentation : 22500
- Large bore piping(m)= 120,000

- Cost : 5 Billion
  - Indirect cost : 2 Billion - 40%
    - Interest(32%), CPI (30%), initial fuel cost (10%), Others(28%)
  - Construction : 1.2 Billion – 25$
  - Equip. Procurement : 1.5 Billion – 30%
  - Design/ Eng : 0.3 Billion - 5%
Nuclear power option included within the national energy strategy

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

Preparation of Infrastructure

• Project Decision Making
  • Feasibility Study
  • Environment Impact Analysis (EIA)
  • Site Evaluation
  • Bid information Specification and Bidding and Evaluation
  • EPC contract
• Construction
• Public information and understanding

PHASE 1
MILESTONE 1
Ready to make a knowledgeable commitment to a nuclear programme

PHASE 2
MILESTONE 2
Ready to invite bids for the first NPP

PHASE 3
MILESTONE 3
Ready to commission and operate the first NPP

Pre-project
Project decision making
Construction

Preparation of Infrastructure

~ 10 – 15 years

Commissioning and Operation

Bidding process
Commissioning

www.pub.iaea.org/MTCD/publications/ninfrastructure.asp
Involvement of the Main Entities

Involvement of the Government
- Ready to make a decision on whether or not to introduce nuclear power
- Ready to invite bids
- Ready to commission and operate the first NPP

Phase 1
- 1~3 years

Phase 2
- 3~7 years

Phase 3
- 7~10 years

Involvement of the Regulatory Body in nuclear power activities
- establishment

Involvement of the Operating Organization
- establishment
Case Study to optimise construction duration
Average Duration for Past NPP Construction 1969 to 1977 in USA

Since 1972, rapidly increase construction period. Why??
## Construction Time Span

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<tr>
<td>Median</td>
<td>80</td>
<td>83</td>
<td>6.67</td>
<td>6.92</td>
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<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>
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<tr>
<td>3 Quartile</td>
<td>105.5</td>
<td>176</td>
<td>8.79</td>
<td>14.67</td>
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<tr>
<td>Maximum</td>
<td>283</td>
<td>302</td>
<td>23.58</td>
<td>25.17</td>
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Resource: Power Reactor Information System in the IAEA database
The Shortest Construction Period

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

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

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

A. Average Past U.S. Nuclear Schedule (Pre-1977)
- Site Prep: 12~18 M
- Construction: 36~42 M
- Start-Up: 6~7 M
- Total: 60 M

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

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

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

E. AP1000 Proposed Schedule
- Site Prep: 18 M
- Construction: 36 M
- Start-Up: 6 M
- Total: 60 Months
Construction Schedule of Japan NPPs

**Construction Duration (month)**

- Green dots: US BWR
- Blue dots: Japan BWR
- Red dots: Japan ABWR

**Year of Fuel Loading**

- TMI

**Improve Construction Method**

- Drawing
- Plastic Model
- 3D-CAD
- 6D-CAD
USA NPPs Construction Experiences
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
OL3 construction site in February 2012

May 2007 : HPV installed,
May 2008 : Start Hot Functional Tests
Aug. 2008 : First Fuel Loading
Nov. 2008 : First Criticality
April 2009 : Start Demo-Run
Construction site: Manpower about 3,500
- Turbine island: Construction work finished and system commissioning preparations ongoing
- Nuclear island: Main civil works to be finished in 2011
- Installation of the main components close to completion
- Piping and electrical installations ongoing

Supplier (AREVA) has informed that most of the works will be completed in 2012. Consequently, operation will start during the early 2015
Major Concrete Dismantling and Demolishing Project in Belene - Site Preparation

- Dismantling and Demolishing
- Reinforced Concrete: 150,298 m³
- Steel Structures: 8,760 t
- Excavation works: 150,923 m³
- Planned Duration: 18 months
  - Mobilization: 2 months
  - D&D: 14 months
  - Demobilization: 2 months
Site opening on 31.07.2008

... and 10 months after ...
Watts Bar Unit 2 – Delayed NPP

- Completed partially Unit 2. (PWR, 1100 Mwe)

- Unit 2 was about 80% completed, stopped in 1988.
  - Resumed on October 15, 2007,
  - Operation in Oct. 2012 (60 M)
  - $2.5 billion USD
Inspection Report of BNP

- Need additional $1.5 B to $2 B (2.5B $→ 4~4.5 B$)
- Completion: Sep 2015 (Total: 60 M ← 96M)
- EPC: Bechtel
- Main reasons: TVA management did not
  - Perform effective warning signs of the EPC contractor
  - Address certain warning known signs that the project was in trouble.
  - Adequately mitigate known problems related to staffing, work order package, timeliness and quality of information provided to the NRC, and procurement of material that require a long time to obtain

NRC letter: TVA has not yet been able to fully address these issues
How can reduce construction duration?
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

With Modularization Method

Milestones

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

**Past**
- Design Start
- Early finish of Engineering

**Current**
- Design Start
- Design Freeze

**Detailed engineering completed before construction start**

**Reduced Site Manpower to 40%**
Front-Loaded Construction Engineering

Previous Design Process

Basic Design

Detailed Design

Construction

Construction Engineering

Front-Loaded Construction Engineering

Basic Design

Requirements from Construction Engineering

Detailed Design

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

Construction

Construction Engineering

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

Schedule loaded with Quantities and Resource
Assign Labor resource
On-site Work Reduction
- Modularization Method -

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)
Sep 27, 2010 Unit 1 CA01 lifting.
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
Advanced Welding Techniques

- Quality welding is crucial and time consuming

- Advanced Techniques
  - Metal Arc Welding,
  - Gas Tungsten Arc Welding
  - Submerged Arc Welding

- Automatic welding equipment is very effective
  - Maintaining high quality
  - Improving the working environment in narrow spaces.
Automatic Welding Machine

Automatic Welding for RCCV Liner

Automatic Welding for Small Bore Piping (CRD piping)

Automatic Welding for Large Bore Piping
Four Season Construction

• Provides “Factory-like” environment for construction during winter
• Secures environment for:
  • Welding
  • Concrete pouring & curing
  • Protection from equipment
• Allows around the clock work
Four Season Construction

Buildings with the All-Weather Structure (Steel and Temporary cover)

Improvement of Work Productivity during winter

Movable Temporary Roof

Winter Productivity Comparison:
- Individual Preparation Method
- All-Weather Method

Graph showing comparison:
- Winter Productivity Rate [%]
- Individual Preparation Method
- All-Weather Method

IAEA
Lessons Learned
Lessons Learned (Project Management)

• Circumstances in Europe and the USA are quite different from 1970’s
  • India, Japan and Korea seems to be different

• Safety requirements clearly should be understand to avoid surprises.
  • Understanding of regulatory practices is essential

• Vendors and their sub-contractors have lost much knowledge and skills
  • New type of competence is needed for new technologies.
  • New advanced safety features are not easily implemented
  • New sub-contractor networks from companies with proven skills
Lessons Learned (Project Management)

- Not underestimate the importance of proven experience
  - How to organize the construction site organization,
  - What resources are needed and when,
  - How the vendor can find competent contractors and how it should manage them,
    - A real competence of manufacturers and sub-contractors is not easy to judge through auditing only
  - How the owner should manage the construction according to schedule
Lessons Learned (Design)

- Ensure before starting the implementation.
  - Licensee’s capabilities and resources
  - Vendor’s capabilities and resources
  - The design has been done to a detailed level,
  - Qualified subcontractors are available

- Challenges from design changes
- Design standards and Material Substitution Management
- Localization and technical transfer
Lessons Learned (Design)

• Inadequate completion of design and engineering work prior to start of construction
  • Delay the start of construction activities at full speed
  • Cause continuous pressures to all involved organizations
  • Lead to attempts to reschedule manufacturing and construction steps,
  • Lead to reduced quality due to time pressure
Lessons Learned (Design)

• Inconsistency and different location in design
  • Different organisations in different places or even in different countries
  • Vendor’s standards and international or imported country
  • Metric system and British units
Lessons Learned (Modularization)

- Difficulties during the module fabrication process.
  - Procurement (Fabrication)
  - Welding technology

- Challenges in the process of modularization construction
  - Assembling technology
  - Lifting deformation control
  - Transportation plan
  - Installing, measuring and positioning technology

Biggest module: Size: $21 \times 14 \times 21$ M
Weight: 850t
The United Arab Emirates is the first country to start the construction of its first nuclear power plant in 27 years, since construction was started on China's first plant in 1985.

As of 30 August 2012, the Barakah-Unit 1 is reported in the IAEA Power Reactor Information System (PRIS) as "under construction".
Financing and Bids invitation and evaluation

IAEA Nuclear Energy Series
No. NG-T-3.9
Invitation and Evaluation of Bids for Nuclear Power Plants

IAEA Nuclear Energy Series
No. NG-T-4.1
Issues to Improve the Prospects of Financing Nuclear Power Plants
Construction management and technology
Human Resource management / Grid Reliability and interface
Once mounted on a tiger’s back, it is hard to control him.
Which tiger is easier to control when we mount?

All the crows and ravens in the worlds are all blackish in general.

The problems do not reside in the hired foreign company but in ourselves.
IAEA assistance package for future NPP Owner/Operator

- Nuclear Power Program Management: How to Become a Knowledgeable Customer
- Establishment of the NPP Owner/Operator organization
- Integrated Management System for the NPP Owner/Operator organization.
- First NPP Feasibility Study preparation
- Interfaces of NPP Owner/Operator with national Regulatory Bodies for the first NPP licensing
- Commissioning Management of the first NPP
- First NPP site selection
- Stakeholder involvement
- NPP bidding process, including preparation of BIS for the first NPP
- Construction Management of the first NPP Project
- Construction Technology of the first NPP Project