Design Requirements of Small Modular Reactors for Specific Site Condition and Utilization in Embarking Countries

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Energy in South East Asia Today – a rising force in global energy

- Abundant potential for renewable energy and widely distributed, but fossil fuels concentrated in a few countries, with Indonesia, Malaysia and Viet Nam having the largest resources;

- Southeast Asia is a net exporter of energy, as exports of coal, natural gas and bioenergy (mainly biofuels) more than offset net imports of oil in energy-equivalent terms;

- Future energy trends in Southeast Asia will be largely determined by interplay of government policies and key energy, economic, environmental and demographic indicators.
Site Studies for the First NPPs in Indonesia

Identified sites for the first NPP: Muria Peninsula, Banten, Bangka Island, East Kalimantan, West Kalimantan, Batam and Nusa Tenggara Barat. **Bangka site is the most ready for NPP construction**
Indonesia has a lot for ultimate heat sink
But, the country has seismic considerations
Peak Ground Acceleration considerations in Indonesia

Masyhur Irsyam (2010) and Badan Tenaga Nuklir Nasional
West Kallimantan Electricity Grid Development Map
Current Electricity Supply in West Kalimantan

Kalbar

- PLN: 314.8 MW
- IPP: 110 MW
- Sewa: 217.7 MW
- Excess: 95 MW

Total: 737.6 MW

500 MVA

325.5 KMS

275 kV

150 kV

705 MVA

Total: 1.205 MVA

1693.2 KMS

Total: 2.018.7 KMS

Kondisi Eksisting Wil. Kalbar per Juli 2018

www.pln.co.id
SMR Deployment Plan in West Kalimantan

Objectives:

• Support the development of strategic mining industries:
  • **1800 MWe** installed capacity required in the next 6 years;
  • The West Kalimantan Province suffers shortage of supply, currently importing 200 MWe from Sarawak, Malaysia.

• Foster the utilization of nuclear energy for boosting economic competitiveness and added values from the mining products in the global market;

• Play active roles in implementing international conventions on the reduction of greenhouse gases to mitigate the climate change;

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Utilities, Users and Embarking Countries Wishes

**BETTER AFFORDABILITY**
- Advances in design, technology and engineering to reduce capital cost
- Economy of serial production with small modular reactors
- Funding and financing options

**SHORT CONSTRUCTION SPAN**
- Advanced construction technology
- Enhanced project management
- Modularization and/or industrial localization in user countries
- Incremental small-module addition

**FLEXIBILITY in Siting & Utilization**
- Not only to increase electrification, also for supplying large industries
- Supply for remote regions with restricted siting
- Coping with higher share of RES

**SUSTAINABILITY**
- Realistic and tangible for long-term National Development Programme
- Reduce CO₂ production by replacing the aging fossil-fuels
- Contribute to mitigating the Climate Change, e.g. the global warming

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Common NPP Technology Goals of Indonesia

• Appropriate size for the (West Kalimantan) grid
• Proven Technology and Regulatory Certainty
• Plant Standardization
• Constructability → Shorter construction time
• Operability and Maintainability
• High capacity factor
• Supply chain (fuel, system, component, equipment)
• Severe accident robustness
• Cost competitiveness: Affordable upfront capital cost and competitive generation cost per kW-hour.
Commercial SMR introduced or known in Southeast Asia

Facts:
- Integral PWR Generation III+, 100 MW(e)
- Conducted IAEA Generic Safety Review
- 1 FOAK unit to be constructed in China in December 2019

Facts:
- Integral PWR Generation III+, 110 MW(e)
- Standard Design Approval in 2012
- 2 FOAK units to be constructed in Saudi Arabia by mid 2020s

Facts:
- Integral PWR Generation III+
- 60 MW(e) x 12 modules
- Undertaking NRC Design Certification Review since 2017
- 1 FOAK unit (12 modules) to be constructed in Idaho Falls
Commercial SMR introduced or known in Southeast Asia

**Facts:**
- High Temperature Gas-cooled Pebble-bed Modular Reactor
- 250 MW(th) per module
- In commissioning in Shidao bay, China
- Promised short construction schedule
- A cooperation on R&D to support Indonesia capacity building is on-going

**Facts:**
- Integral PWR Generation III+
- 50 MW(e) x 2 modules
- Deployed as nuclear icebreakers (2 units)
- Land-based version for import

**Facts:**
- Boiling Water Reactor, Generation III+
- 300 MW(e), natural circulation
- Jointly developed by GE and Hitachi
- Development supported by both the Governments of Japan and the United States
Typical Stages in Design & Engineering of NPP Project

- **Conceptual**
  - Feasibility: Business case, pre-project planning and review of requirements
  - Site license Application

- **Preliminary**
  - Constructability: Schematic layouts, schedule, and cost estimation
  - Licensable Design

- **Basic**
  - Financing: Budgeting, execution plan, safety case and environmental impact
  - Construction License Application

- **Detailed**
  - Procurement: Specification & supplier qualification, and limited work authorization

10 to 30 years

Nuclear does take time from Conceptual to Ready-to-Market and Ready-to-Build
Typical Project Completion Schedule

- **Developer**
  - Contracts with reactor vendor

- **Prepare application**
  - EIA approved

- **Detail design**
  - Order Long-lead items

- **Plant construction**
  - Construction License issued

- **Commissioning**
  - License issued

- **Operating**
  - First revenue


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<table>
<thead>
<tr>
<th>Site Condition</th>
<th>Issues (Indonesia case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic, hydrology, meteorology</td>
<td>Many site lie on volcanic and sedimentary rocks of Pleistocene. Site geology mainly consists of: • Soil zone • Upper tuff zone • Middle sand stone zone • Lower tuff zone</td>
</tr>
<tr>
<td>Cooling water availability and temperature</td>
<td>• Sea water temperature in both dry and rainy seasons ranges approximately from 28°C to 32°C. • The design seawater temperature for main condenser shall be 30°C • The seawater in some sites is muddy, the seabed is so flat that 10 m depth is located about 1000 m off the shoreline</td>
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## Site Imposed Requirements

<table>
<thead>
<tr>
<th>External Events</th>
<th>Issues (Indonesia case)</th>
</tr>
</thead>
</table>
| Natural disasters        | • The plant design shall consider the probability of natural disasters in the region such as earthquakes, tsunami, typhoon, and flooding (river and coastal flood).  
  • The largest tsunami took place in December 2004, in a non-nuclear siting  
  • As all potential sites on the seashore, the largest tidal wave, tsunami and hurricane driven wave shall be estimated |
| Man-made hazards         | The plant integrity must be assured for any man-induced event that might occur due to activities (including sabotage), near the site                   |
# Site Imposed Requirements

## Site infrastructure

The planning for site preparation and construction activities shall consider the development of infrastructure:

- Considerably long connection to existing 500 kV transmission line
- Improvement and widening of access roads and local ports, and
- No large fresh water source and very distant from potable water distribution

## Emergency preparedness and response

To follow the IAEA General Safety Standards No. GSR Part 7 that establishes the requirements for preparedness and response for a nuclear or radiological emergency which takes into account the latest experience and developments in the subject:

Should incorporate the result of the on-going IAEA Coordinated Research Project on determining the size of EPZ, as well as best practice in experienced nuclear regulators
Plant Design Requirements

**Design Simplicity**

The design should aim for simplicity to minimize the possibility of operators and maintenance errors and eliminate potential adverse safety system interactions. Design simplicity should address:

- Using the minimum number of components to perform a particular function;
- Minimizing the demands on operating staff during normal operation and during transients, incidents and accidents;
- Providing equipment layout and arrangements which simplify and facilitate access, inspection, maintenance and/or replacement;
- Taking measures to assure simplification of construction and decommissioning
Plant Design Requirement: Standardization

Although NPP design shall be adjusted for the local site conditions, such as seismic design and ultimate heat sink, standardization required to:

- **Reduce cost:**
  - Design of NPP and its components be standardized to the maximum practical extent;
  - For deployment in the same region, site differences should not significantly reduce the degree of standardization

- **Enable sharing information among operators:**
  - Support operator training; operators from owners’ group share lessons-learned
  - Users of standardized NPP can share information regarding technical problems and can solve the problems together;

- **Facilitate maintenance:**
  - Standardization will facilitate the replacement of components and the availability of spare parts;
  - Ensured by stability and long term viability of the supply market for critical components over the plant life time

- **Confirm a robust supply chain:**
  - Vendors should assure ‘diverse’ supply for replacement by manufacturers other than the original manufacturers;
General definition and objectives:

- (1) optimize fabrication, assembly, test, procurement, delivery, service, and repair, and (2) assure the best cost, quality, reliability, regulatory compliance, safety, and time-to-market.

Modularization:

- Not only the feature of small modular reactor, but it has been implemented in different degrees for large reactor designs and construction;
- Reactor designers differ on the accepted definition; some focus on shop-fabricated components to ease transport; others on integrating the systems for simplification;

Employment opportunities in vendor countries’ versus industrial localization in the user countries:

- Embarking countries expect some degrees of industrial localization to reduce capital cost and capacity building – should be seen as cost reduction opportunities;
- May be restricted by nuclear export control;
- Start prioritizing on the balance of plant and civil structure as host country scope
- However, over-estimating the domestic industrial capacity, particularly on quality standards, will result in severe difficulties later, so it is essential to perform a thorough survey of local capabilities at an early stage.
Plant Design Requirement: Constructability

- **Use advanced construction technology and project management:**
  - Adopt and apply proper construction technology, including modularization;
  - Construction shall not start before design completion;
  - Assure strategic and operational planning by the owner

- **Availability of qualified workforce for the whole construction span:**
  - Design, construction process and procedures should allow optimized use of both local workforces at site and prefabrication at factories or at site;
  - As promoted by SMR, prefabrication at factory can effectively reduce construction time, however it may also increase construction costs and discourage local industries participation;

- **Choosing the right and experience builder and architect engineer:**
  - Nuclear new build is not only about selecting the right technology, but also to make sure that particularly for embarking countries with limited resources, experienced qualified builders are available to start and complete construction on time and on budget;
  - Early technical engagement or communication between owner and A/E would be useful.
Progress and Impediments in Newbuild Projects

- 55 nuclear power reactors under construction in 17 countries, including 4 embarking countries adopting Generation III/III+ advanced reactors;
- More embarking countries with planning to build advanced reactors near term;
- 3 NPPs with SMRs of different technology categories in advanced stage of construction, all will be in operation in 2020/2021 in Argentina, China & Russia;
- Dozens of options for near-term deployable reactor designs both large and small modular reactors.

- Significant delays and budget overruns in construction projects in nuclear power countries, due to various causes;
- Abandonments of projects at advanced stage of construction, also in nuclear power countries;
- The construction spans of the 3 first of kind SMR NPPs have not reflected the design objective of SMRs;
- Dozens of options for near-term deployable reactor designs both large and small modular reactors;
- Competitiveness of generating electricity cost against fossil and renewables even in countries with nuclear power;
- Too high upfront capital cost for embarking countries with suitable financing options.

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Challenges in Deploying NPP in Indonesia

• National Position:
  • Awaiting for a Go-Nuclear from the elected President of Indonesia
  • Coordination amongst the related government organizations

• Many remote areas with small electricity grid would require SMR deployment, but **SMRs lack of reference design in commercial stage**

• **FOAK technology** and investment risks are high for developing countries

• **Cost competitiveness** of nuclear compared to available alternatives

• **Public Information and Acceptance**:
  • Despite 65% public acceptance, the remaining 10% against could be determinant;

An updated IAEA Integrated Nuclear Infrastructure Review should be conducted to analyze progress and gap from the first INIR Mission in 2009
Summary and Recommendations

• Soaring costs of nuclear newbuild projects beyond the original estimate caused disappointment, controversies, and cancellation of projects;
• Maximum use of standardized design and proven technology should be adopted by SMRs. Deviations will generally be costly;
• Simplification, design standardization, manufacturability of systems and components, and constructability are among key factors to facilitate lowering the capital cost and shorten the time-to-market;
• Embarking countries look for reference model for SMR; successful construction project on budget, on schedule – model project management;
• Industrial and manpower capacity building in embarking countries can be done in manufacturing and construction activities, through localization and domestic industrial participation – affected by lower labor rates;
• Optimized time for R&D, design review/licensing and construction.
Thank you, please visit Indonesia
Questions to the Distinguished Participants

1. What **external hazards** and **site specific issues** that could affect design of the reactor, site preparation schedule and costs in deploying an SMR in your country?

2. How to anticipate and mitigate the **First-of-a-Kind Engineering** risk and how do you realistically define a **Proven Technology**?

3. **To SMR designers:** the target construction schedule for advanced large LWRs is 60 months (1990s), hardly achieved 😜. Some SMR designers claim construction span of 3-4 years, what are the rationales? **What are the realities?** What lessons-learned you take from the delay in the on-going newbuilds (large reactors and SMRs)?

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