Indian Participation in INPRO – as INPRO Member's Perspective

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56th IAEA General Conference, INPRO Side Event on
Enhancing Global Nuclear Energy Sustainability: Briefing on the INPRO
19th September, 2012

Indian national nuclear power programme and interests

Indian nuclear power programme is focused on

- Long term sustainability, through 3 stage programme and closed nuclear fuel cycle:
  - Deployment of PHWRs and LWRs
  - Development and Deployment of fast breeder reactors, including those utilising metallic fuels
  - Development and deployment of nuclear reactor systems based on thorium fuel cycle
- Technical and institutional innovations:
  - Advanced reactors including reactors for non-electric applications
  - Advanced fuel cycle and reactors allowing sustainable use of thorium
  - Activities to improve sustainability

India is interested in INPRO activities leading to facilitation of above goals

- India is also participating in scenario studies and further development of INPRO Methodology

Overview of Indian contributions to INPRO

- India is one of the **founder members** of INPRO
- Contribution towards **development and validation of INPRO methodology**
- **Participation in Collaborative Projects** – As lead country in many projects
- Participation in **INPRO Dialogue forums**
- **Chair of INPRO steering committee** for ~ 4 Years (8^{th} - 14^{th} SCM)
- **Cost free experts**, and
- **Extra-budgetary contributions**

Indian participation towards development of INPRO methodology

- Contributions to **INPRO methodology documents**
  - IAEA TECDOC 1362
  - IAEA TECDOC 1434
- **National case study with AHWR** as reference case for validation of draft INPRO methodology
- Contributed to **preparation of INPRO manuals** (IAEA TECDOC 1575)
- **Assessment of "INS for hydrogen generation"** and suggestions for improvement of INPRO methodology for non-electric applications
- **National case study** on "International Fuel Cycle and Option of Closed Fuel Cycle with Fast Breeder Reactors"
- Participation in **joint assessment of "Closed Nuclear Fuel Cycle with Fast Reactors"**

Indian Participation in collaborative projects (India as lead country)

Collaborative Project	Participants	Indian contributions
COOL (Investigation of Technological Challenges Related to the Removal of Heat by Liquid Metal and Molten Salt Coolants from Reactor Cores Operating at High Temperatures)	Brazil, China, Czech Republic, Germany, Hungary, India, Italy, Republic of Korea	▪ Review of thermo physical properties data for Lead-Bismuth Eutectic (LBE) ▪ Heat transfer studies on LBE using CFD, review of correlations, and development of new correlations ▪ Experimental and theoretical studies on LBE melting and solidification; LBE loop; and oxygen sensor
AWCR (Advanced Water Cooled Reactor Case Studies in Support of Passive Safety Systems)	Argentina, India, Republic of Korea	▪ Experimental results for stabilisation of natural circulation, stratification, and start-up of natural circulation ▪ Combined analysis using system analysis and CFD codes for thermal mixing
DHR (Integrated Approach for the Modeling of Safety Grade Decay Heat Removal System for Liquid Metal Reactors)	China , India, European Commission (EC), Republic of Korea, Russian Federation	▪ Analyses considering different parameters for decay heat removal system and comparison of results.

Indian Participation in collaborative projects

Collaborative Project	Participants	Indian contribution
GAINS (Global Architecture of Innovative Nuclear Energy Systems Based on Thermal and Fast Reactors Including a Closed Fuel Cycle)	Argentina, Belgium, Canada, China, Czech Republic, France, India, Japan, Republic of Korea, Russian Federation, Slovak Republic, Ukraine, United States	▪ Contributed results of in house developed code TEPS (Tool for Energy Planning Studies) for homogeneous and heterogeneous scenarios ▪ India's proposed nuclear strategy during the next century involving the use of fast reactors and thorium fuel cycle ▪ Data on PFBR as part of reactor database considered for various cases ▪ Contributed towards development of Key Indicators
FINITE (Fuel Cycles for Innovative Nuclear Energy Systems based on Integrated Technologies)	Argentina, China, the Czech Republic, India and the Russian Federation	▪ Document on national energy scenario and fuel cycle options ▪ Applicability of INPRO methodology to assess Indian nuclear energy system ▪ Important considerations, particularly, issues related to thorium fuel cycle and MSRs identified

Indian Participation in collaborative projects

Collaborative Project	Participants	Indian contribution
ThFC (Further Investigation of the ^{233}U/Th Fuel Cycle)	Canada, China, EC, India, France, Republic of Korea, Russian Federation, Slovak Republic, Ukraine	▪ Results of studies on ^{233}U-Th fuelled AHWR and AHWR300-LEU presented
ENV (Environmental Impact Benchmarking Applicable for Nuclear Energy System under Normal Operation)	Belarus, Brazil, Czech Republic, France, India, Indonesia, Kazakhstan, Republic of Korea, Russian Federation, Slovak Republic, Ukraine	▪ Analyses of dosages from various nuclides using various pathways atmospheric, Marine, River media ▪ Atmospheric - Pathways of exposure through Inhalation, immersion, ingestion considered - Tritium and Carbon are the main contributors ▪ Marine and River- Exposure pathway: Ingestion considered
PGAP (Performance Assessment of Passive Gaseous Provisions)	Belgium, France, India	▪ BARC methodology APSRA (Assessment of Passive Systems ReliAbility) used for performance & reliability prediction of passive decay heat removal system of French GFR ▪ Comparison with EU methodology RMPS (Reliability Methods for Passive Systems)

Indian participation in the INPRO Dialogue Forum Meetings

- Workshop of the INPRO Dialogue Forum on **Nuclear Energy Innovations**
- INPRO Dialogue Forum on Nuclear Energy Innovations: **Multilateral Approaches to Sustainable Nuclear Energy Deployment – Institutional Challenges**
- INPRO Dialogue Forum on Nuclear Energy Innovations: **Common User Considerations for Small and Medium-sized Nuclear Power Reactors**

Recent and proposed future participation

- **SYNERGIES** (Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability)
- **ROADMAPS**: Roadmaps For a Transition to Globally Sustainable Nuclear Energy Systems
- **ENV-PE**: Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems
- **RISC**: Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences
- Investigation of options for a **new international project on fast reactors, fuel cycles and materials R&D**
- **Dialogue forum on Drivers and Impediments** for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems

Other contributions to INPRO

- **Cost-free experts (12 Man months)**
- **Extra budgetary contributions** for the years 2007, 2008 and 2010 ($50,000 each year)
- **Contribution for further period** under active consideration

Benefits to India from participation in INPRO activities

- Validation of many design and data related inputs
- Comparative evaluation of performance of in-house computer codes and assessment tools with those being used in other Member States
- Enhanced opportunity to interact with international experts and exchange of knowledge and experience

Indian Perspectives on INPRO

- World needs large scale deployment of nuclear energy to avoid further global warming - volume of deployment requires closed nuclear fuel cycle
- Post Fukushima enhanced safety is one of the most important issues
- Other key aspects of enhanced security, sustainability, economics, proliferation resistance, and waste management along with safety also need to be intrinsically addressed in the design of INS
  - **INPRO methodology is an ideal tool to carry out assessments of various INS leading to identification of R & D areas for new technologies**
  - **These areas could be addressed through technical and institutional innovations and achieved through INPRO CPs**

INPRO contributions are important in future development and deployment of nuclear energy

Expectations from INPRO

- Facilitate innovations that help develop solutions for addressing issues related to large scale deployment of nuclear power, including in regions with high population density
- Encourage vision-driven approaches that lead to products, which would help enhance demand for, or adoption of, nuclear power
- More focus on activities leading to safety studies – ultimately leading to greater availability of inherently safe designs
- Guidance to new-comer countries in deployment of reactor systems as well as in establishing their long term sustainable strategies
- Continue to facilitate long term scenario studies at national, regional, and global level – may also include non-electricity applications (especially for transport)

Conclusions

- INPRO is a vital forum for fostering international cooperation in advanced nuclear energy systems
- India has been an active member of INPRO since its inception
- India has contributed extensively towards development of INPRO methodology as well as participated productively in various CPs and Dialogue Forums
- INPRO Members, including India, have benefitted from participation in various INPRO activities
- IAEA should continue to support and further strengthen INPRO and allied activities
- India will continue to participate and support INPRO activities in future

Thank you

भाभा परमाणु अनुसंधान केंद्र

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