Challenges in Regulation of New & Emerging Innovative Technologies

Utkarsh S C
Head, Nuclear Safety Analysis Division

Views expressed in this presentation are based on my experience working in this field and not to be treated as views of AERB

Outline

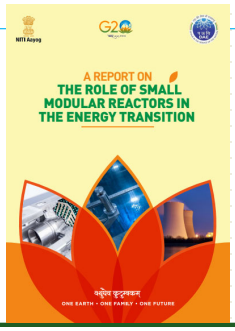
- Energy / Power Requirement
- Historical Development of Technology
- New & Emerging Innovative Technologies
- Expected challenges due Innovative technology
- AERB Regulatory Experience
- AERB Preparedness
- Summary

Energy / Power Requirement

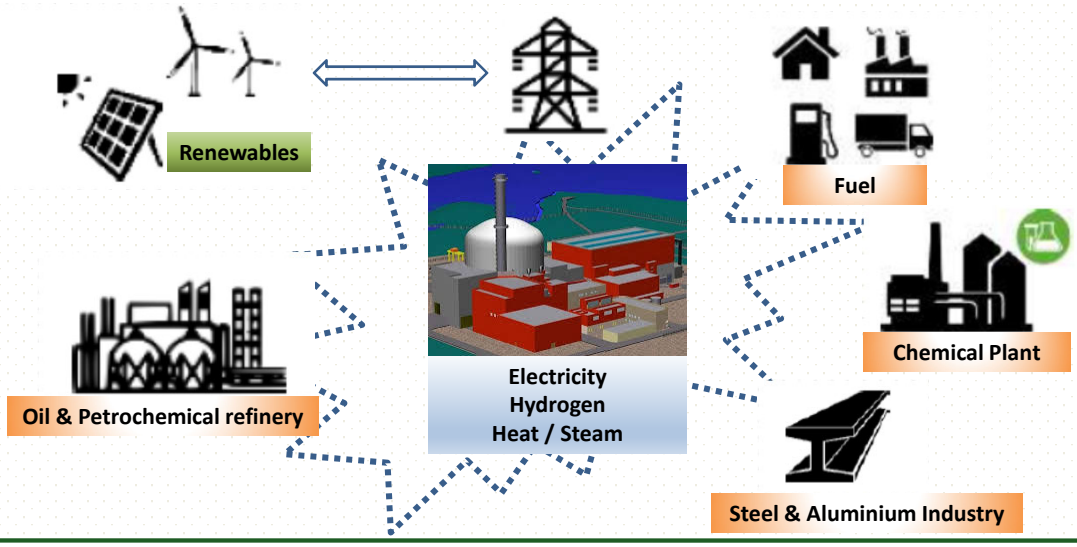
	Category	Installed Generation Capacity (MW)	% Share in Total
Fossil Fuel	Coal	2,08,189	48.4%
	Lignite	6,620	1.5%
	Gas	25,038	5.8%
	Diesel	589	0.1%
	Total Fossil Fuel :	2,40,437	55.9%
Non-Fossil Fuel	RES (Incl. Hydro)	1,82,045	42.3%
	Hydro 46,928		10.9%
	Wind, Solar & Other RE 1,35,116		31.4%
	Wind 44,969		*10.5%*
	Solar 74,307		*17.3%*
	BM Power/Cogen. 10,262		*2.4%*
	Waste to Energy 584		*0.1%*
	Small Hydro Power 4,995		*1.2%*
	Nuclear	7,480	1.7%
	Total Non-Fossil Fuel :	1,89,525	44.1%
	Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel)	4,29,961	100%

Source : Central Electricity Authority (CEA)

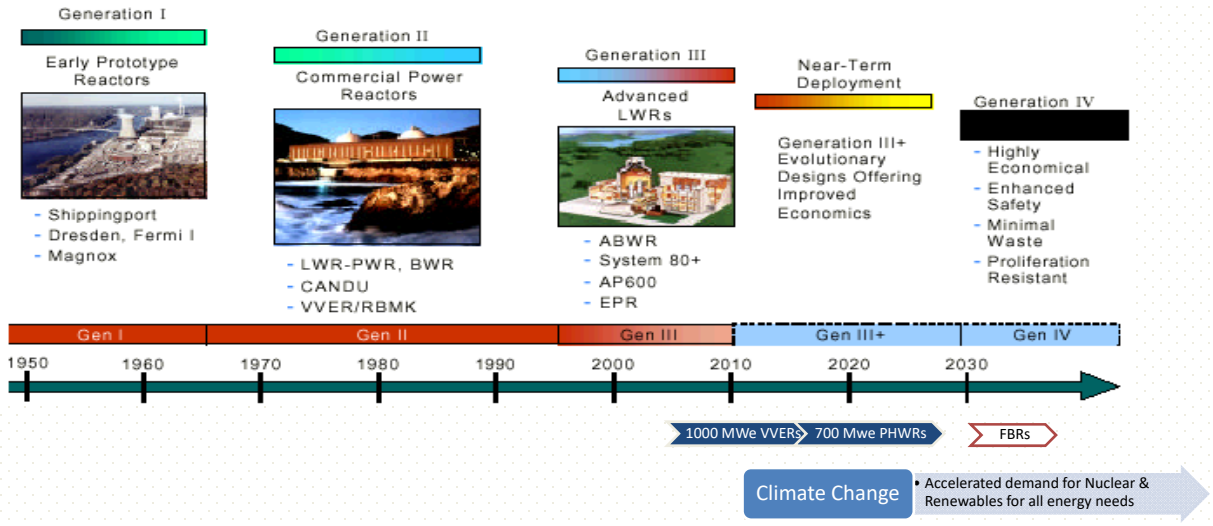
- Traditional use - baseload power to large power grids
- Clean Energy – Nuclear with Renewables
  - Industrial Decarbonisation: Transport & Manufacturing
  - Greater load following (to replace fossil fuels)
  - Smaller power grids (isolated/remote off-grid locations)
  - Waste minimization



Energy / Power Requirement



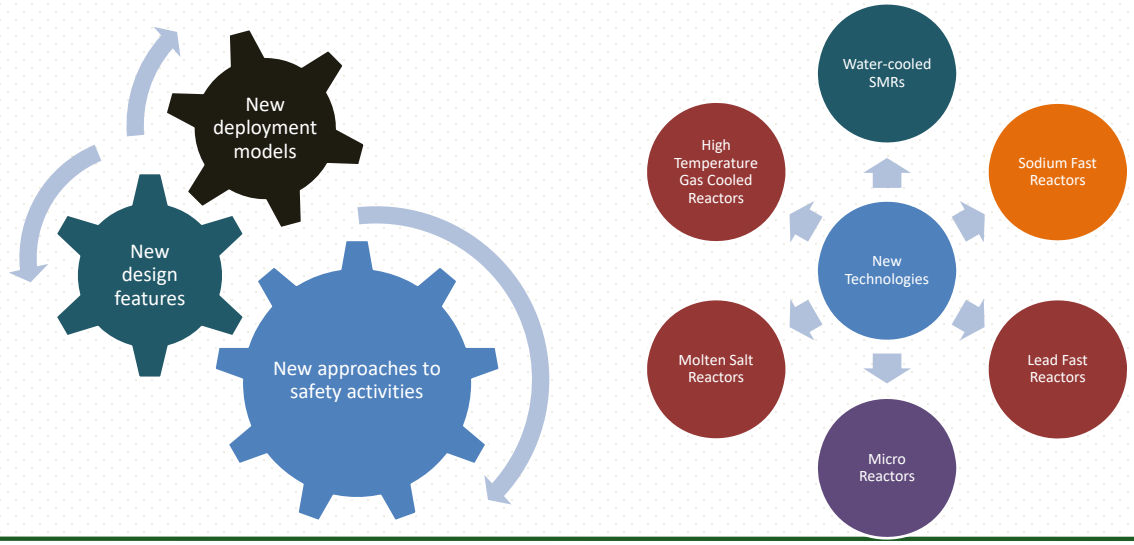
Historical Development of Technology



New & Emerging Innovative Technologies

- An innovation in the context of the safety assessment of NPP is considered to be a new type of SSC(s) or a specific mode of operation relevant to safety that has not previously been used or is used in a new way, for which:
  - Proven engineering practices for nuclear power plants are not fully defined; or
  - Existing practices or safety standards need to be interpreted, and judgement used for their application.
- Within this definition, innovations fall into a spectrum (degree of innovation) spanning the following three areas:
  - Minor upgrades to well-established technological solutions in nuclear power plants;
  - Evolutionary changes to existing solutions with some new characteristics;
  - Technologies with new characteristics or properties previously not used in nuclear power plants.
- A design with multiple innovations that includes conceptual changes compared to existing plants is referred to as an innovative design

New & Emerging Innovative Technologies



Expected challenges due Innovative technology

- Nuclear fuels
- Reactor coolant and working medium
- Working principles and Phenomena
- Instrumentation and control
- Approaches to reactor operation
- human–machine interfaces
- Surveillance, inspection and maintenance
- Materials
- Codes and standards
- Use of proven engineering practices in a different context
- Manufacturing and construction
- Non-electricity generation applications
- Multi-unit and multi-module designs
- Transportable concepts or siting concepts
- Computer codes

Expected challenges due Innovative technology

- FUEL CONCEPTS
  - Ex: tri-structural isotropic (TRISO) fuel, molten salts etc.
  - Behavior in different plant states - fuel qualification programme
  - On-site transport, handling and storage of irradiated and unirradiated fuel
  - Fuel cycle back end and long term management
  - Margins in safety performance, acceptance criteria and design limits

- NON-WATER REACTOR COOLANTS
  - Ex: sodium, lead, lead–bismuth, molten salts etc.
  - Experience with sodium as reactor coolant.
  - Thermo-physical/nuclear properties – variation with time.
  - Coolant parameters in different plant states - freezing etc.
  - Chemistry – quality/impurities, storage & disposal etc.
  - Different support system design - significant source terms, high corrosion, negligible leak requirement
  - New PIEs/hazards - relocation of radioactive source
  - Application of common NDTs & standards etc.

Expected challenges due Innovative technology

- INSTRUMENTATION AND CONTROL
  - Digital architecture - Automation or AI
  - Difficult to predict failure modes - disable operator functions, misleading indications
  - Independence of defence in depth levels
  - New vulnerabilities - cyber-attacks

- PASSIVE SAFETY FEATURES
  - Generally weak driving forces - stability & failure modes.
  - Scale testing and pre-operation testing.
  - Reliability

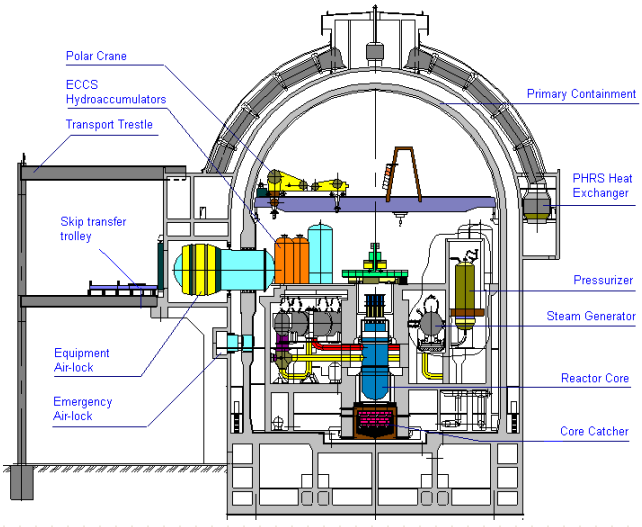
- ADVANCED MATERIALS & MANUFACTURING
  - Lack of knowledge of the relevant failure mechanisms,
  - Corrosion, wear and tear, and ageing mechanisms
  - No appropriate established codes or standards

- NON-ELECTRICITY GENERATION APPLICATIONS
  - Ex: hydrogen production, heat generation, desalination often via co-generation
  - Impact of facility on NPP and NPP on facility and accident management

Expected challenges due Innovative technology

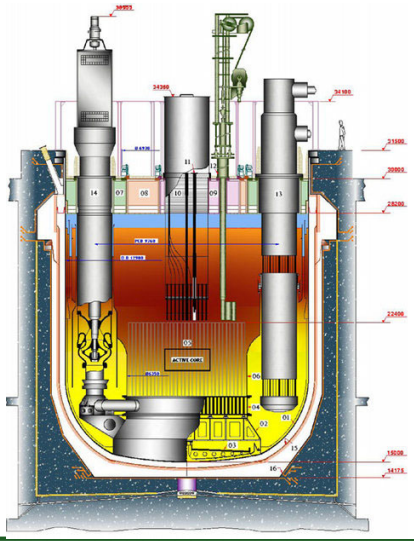
- HUMAN AND ORGANIZATIONAL IMPLICATIONS
  - Different organizational arrangements – SMRs, reduced/no staffing at site.
  - Innovative modes of operation - remote, AI & ML supported, loss of operator skill
  - Shared control room for multi modules
  - Support for maintenance & inspection
  - On-site and off-Site Accident Management
- SAFETY ANALYSIS
  - Validated computer codes
  - DSA: PIEs, acceptance criteria, severe accident/hazards, etc.
  - PSA: SSCs reliability data, human reliability, passive system reliability etc.
  - Unique plant operational states
  - Passive and inherent design features
- MULTI-UNIT AND MULTI-MODULE DESIGNS
  - Combinations of operational states and configurations
  - shared systems Impact – fault transfer, CCF
  - Human interactions and EPR
- TRANSPORTABLE NUCLEAR POWER PLANTS
  - Site change, potential hazards change, safety analysis change
  - Monitoring and EPR
  - Security

AERB Regulatory Experience – KKNPP-1&2



- Reference Plant + Many FOAK Features
- Licensable in Russia
- PSAR supported by Topical Reports (Experimental demonstration)
- AERB Codes and Guides (generic and Intent of technology specific requirement)
- IAEA, IAEA Review of VVER and International references for PWRs
- RF Regulatory Body Review Recommendations
- Licensing process and stages almost same (extended commissioning)

AERB Regulatory Experience – PFBR



- FBTR Experience (commissioned in 1985)
- AERB Codes and Guides (generic and Intent of technology specific requirement)
- Developed **safety criteria for the design** of PFBR and compliance of PFBR design with this document.
- PSAR supported by extensive testing and Experimentation at IGCAR – test reports
- International experience on FBRs
- Licensing process and stages almost same (extended commissioning)

AERB Preparedness - Regulatory Instrument

Regulatory Process
Radiation Protection
Emergency Preparedness
Rad. Waste Management
Industrial Safety

Siting
NPP – Design
NPP – Operation
NPP – Quality Assurance
Fuel Cycle Facilities

- Nuclear Safety Fundamentals and high level requirements remains same
- Adequate Technology Neutral Regulation to address various designs – further work in progress
- Technology specific covered for WCRs & SFRs – further optimization based on experience
- Technology specific aspects may need to be evolved based on type of technology

AERB Preparedness - Safety Review & Licensing

Repeat Design
- Previously reviewed by AERB
- Site specific modifications

Exact Replica

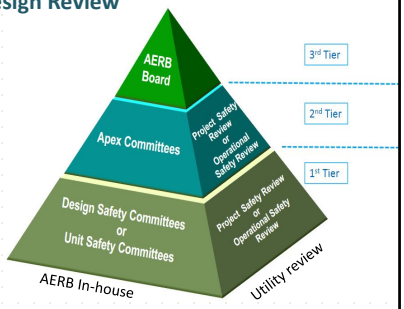
Additional/modified safety/design features or capacity enhanced. Review of changes

New Design
- Previously not reviewed by AERB.
- Detailed review & assessment, independent verification, regulatory R&D

Commercial design operating elsewhere - Reference Plant Design

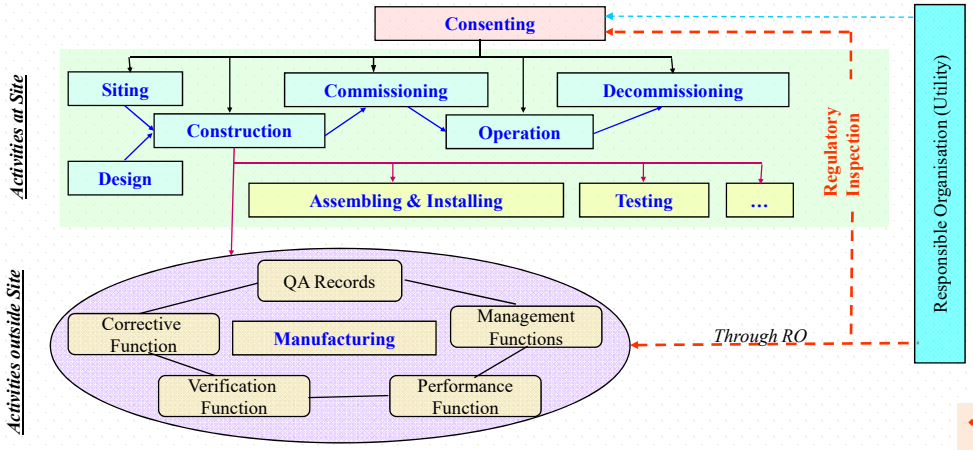
Design not in operation at a commercial level - Prototype Design

Pre-Application Consultation
- Early Site Review
- **Early Design Review**



- Licensing process: Historically developed and adaptable to new designs
- Innovative system / design - Qualification by experiments, analysis
- Technical Support – TSO, R&D institutes, Academic institutions and Retired Experts

AERB Preparedness - Regulatory Oversight



- Off-site construction / commissioning activities
  - Factory built modules, factory fuelled modules – inspection & verification
  - Transportation of fuelled modules (interfaces with international agencies)

- Counterfeit?
- Falsification?

AERB Preparedness – Other Aspects

- Multi-Module considerations
- Number of Technologies and Number of Units - Human Resource
- Public Awareness & Confidence – especially new technology
- Additional consideration w.r.t Private & Other Entities
  - Design authority Construction, Commissioning, Operation, Maintenance, etc.
- Complete Fuel Cycle including waste management

- *Progressive In-house study on new and innovative technologies including SMRs*
- *Participation in IAEA's Review of Safety Standards Applicability to Novel Advanced Reactors*
- *Participation in IAEA NHSI-RT-WGs*

Summary

- Established regulatory framework evolved over time applicable for new build
  - Schedule and level of checks – graded approach
  - Stage-wise Clearances accorded after thorough review
- Most of the requirements are generic (technology neutral) and can be applied to new technologies
  - Technology specific requirements covered for WCRs & SFRs
  - Technology specific aspects may need to be evolved based on type of new technology.
  - AERB is progressively getting involved in multi-lateral and bilateral forums
- Further study and progressive revamping of Regulations and Processes - in progress

Safety is an ever moving target, hence there will be challenges at any given time

Thank you

References

- *IAEA SRS 123: Applicability of IAEA Safety Standards to Non-Water-Cooled Reactors and SMRs*
- *IAEA DS537: Safety Demonstration of Innovative Technology in Nuclear Power Plants*