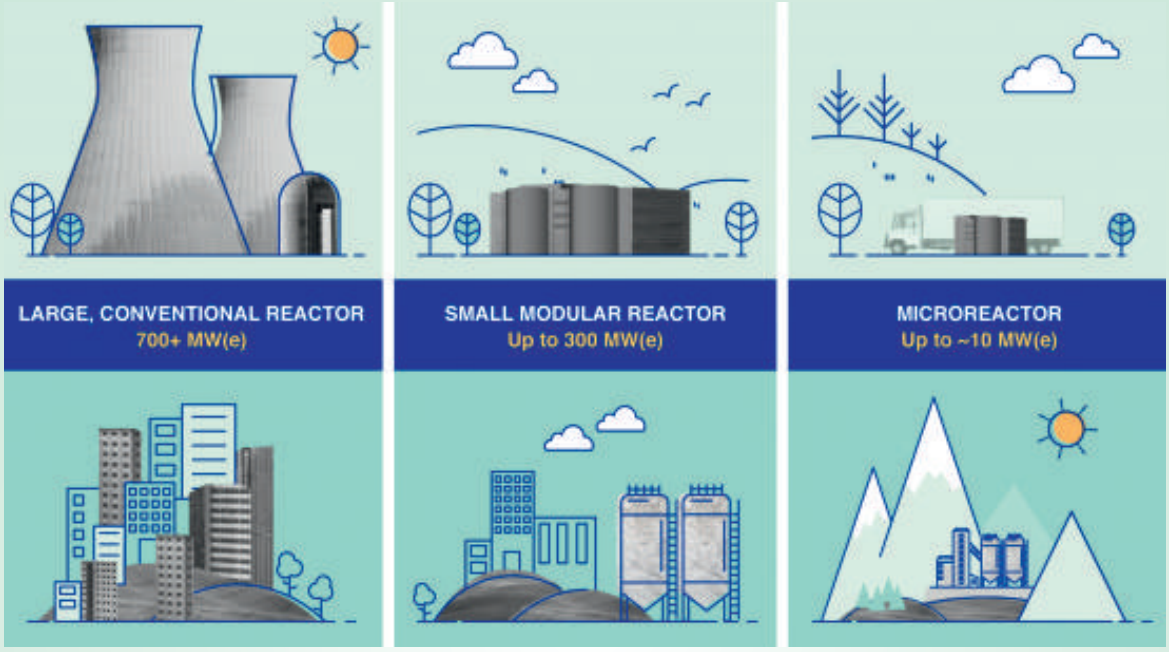
INDIAN NUCLEAR SOCIETY NEWS



Small Modular Reactors (SMRs) have a power capacity of up to 300 MW(e) per unit. Many SMRs, which can be factory-assembled and transported to a location for installation, are envisioned for markets such as industrial applications or remote areas with limited grid capacity. (Image: A. Vargas/IAEA, IAEA News November 4, 2021)

TECHNOLOGIES FOR
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QUARTERLY BULLETIN OF
INDIAN NUCLEAR SOCIETY

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FROM THE EDITOR'S DESK

My Dear Fellow INS-Members,

Greetings.

First and foremost, the INS International Conference, INSIC-2023 with the theme, 'Nuclear for Clean Energy Transition' will be held from December 12 -15, at the DAE Convention Centre in Anushaktinagar, Mumbai. The First Announcement is in this issue, and all are requested to take note of it and plan to participate in the Conference.

In the previous issue of the INS Newsletter, Prof. B.N. Jagatap, in his President's note highlighted the relevance of Sustainable Development Goal 13 – Clean Climate, of the UN Agenda-2030, and the debate/discussions it has initiated. He has quoted from a study that by 2050, to restrict global warming to 1.5° C, the energy mix should have generated several folds of nuclear energy, and renewable energy as compared to what it is at presently.

In this context, the role of Small Modular Reactors (SMR) as a potential source of 'clean energy' has been a subject of many discussions, and is summarized by the article in this issue, 'SMR: Potential game-changer for Nuclear Industry in India' - compiled by Dr A Rama Rao.

The Vivekananda International Foundation (VIF): Task Force Report - 'India's Energy Transition in a Carbon-Constrained World' of December 2022, also discusses the energy mix that India should have to meet the net zero emission status by 2070, as stated by India at the Glasgow Conference of Parties (COP 26). The VIF task force is headed by Dr. Anil Kakodkar, Former Chairman of the Atomic Energy Commission. This report points out that: Power sector accounts for only 45 percent of India's emissions. Therefore, the goal of net zero emission will not be attainable without going beyond the power sector to include transport, residential uses and industry (1).

Hence, the SMRs appear to be a viable alternative to thermal power and are envisaged as an assembly-line product with minimal on-site fabrication and preparation and will substantially reduce the lengthy construction times that are typical of the larger power reactor units.

While the pros for SMRs appear to be viable in the Indian Energy scenario (along with large conventional reactors) there are some who are not as optimistic in the International Energy scenario. As scientists and engineers, it is appropriate that we also read what the naysayers say and why. Leonard Hyman & William Tilles discuss the Pros and Cons of Modular Nuclear Reactors in www.oilprice.com. Their views are:

1. Customization in nuclear power led to isolated and non-transferable experiences and limited the industry's growth.
2. Small modular reactors are a new approach that allows for standardization and assembly line efficiency, but also offer logistical and funding challenges.
3. The future of nuclear energy could rely, in part, on the development and implementation of small modular reactors.

They sum up by saying: There are at least 21 SMR technologies as of date. Which of these will compete and be opted for by end-users needs to be seen, considering nationalistic and security issues? Finally, SMRs, while welcome, neither substantially reduce nuclear costs nor cure the waste disposal problem, although they should reduce the financial burden inherent in big nuclear projects. **In other words, the Authors are saying that though nuclear energy, remains the most expensive and environmentally controversial, but are confirmed reliable energy sources with low carbon emissions. Hence, they conclude by saying that SMRs may be the option to reach zero-emission targets - is there a better way? (2)**

Taking a really pessimistic stand, Michael Barnard, in his post: "The Nuclear Fallacy: Why Small Modular Reactors Can't Compete With Renewable Energy?" that appeared in the January 18, 2023, issue of CleanTechnica, states that (3, 4):

Small modular reactors won't achieve economies of manufacturing scale, won't be faster to construct, forego efficiency of vertical scaling, won't be cheaper, aren't suitable for remote or brownfield coal sites, still face very large security costs, will still be costly and slow to decommission, and still require liability insurance caps. **They don't solve any of the problems that they purport to while intentionally choosing to be less efficient than they could be. Thermal generation like coal or nuclear likes big boilers. It's the inverse of liquid hydrogen storage having to be as close to balls and as big as possible, thermal efficiency is better in big globes because it minimizes surface area while maximizing volume. Want thermal efficiency? Scale up.(5)**

However, several countries are upbeat about the SMR as an industrial venture. In particular, the US-Department of Energy (DOE) is upbeat about SMRs and hopes that the development of standardized SMR designs will also result in an increased presence of U.S. companies in the global energy market. If a sufficient number of SMR units were ordered, it would provide the necessary incentive to develop the appropriate factory capacity to further grow domestic and international sales of SMR power plants.(5)

Let us too hope that we will have our own design of a SMR that will help meet our clean energy needs, that will be economical and competitive in international market in support of and meeting clean climate goals.

While there is a general consensus that

nuclear power is a clean energy source, its preference over other energy sources among the public is generally challenged by its operation and maintenance costs, which by conservative estimates are >60% of the total nuclear power generation cost in contrast with <20% of the cost of electricity generation from conventional thermal power [6]. In addition there are numerous concerns regarding the system safety and reliability. Hence, the challenges for the growth of the nuclear sector involve the enhancement of safety, the preservation of availability and the reduction of the costs associated with the operation and maintenance of the plants. The article by Santhosh et al., - Artificial Intelligence based Transient Identification and Operator Decision Support System for PHWRs (Diagnostic system), describes how the operational safety can be enhanced using machine learning and artificial neural networks.

This issue also has a comprehensive "Nuclear News' - including snippets on Small & Micro Reactors, and Green Hydrogen, compiled by Shri S. K. Malhotra, and interesting information about little known facts in nuclear science from Dr. M.R. Iyer

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(M.G.R. Rajan)

SMR: POTENTIAL GAME-CHANGER FOR NUCLEAR INDUSTRY IN INDIA [1]

Compiled by Dr. A Rama Rao

1. Current Energy Position and commitments

By 2050 the estimated power demand in India is 20,000 TWh/year. The current generation is about 10,000 TWh/year which is presently equivalent to total power in EU. By generating 10,000 TWh/year of power, India is emitting about 2.35 BT CO2/yr whereas globally the emission is about 60 BT CO2/yr. India emits more than 600 g CO2 /KWh. In COP26, India has agreed to reduce to 1.0 BT CO2/yr by 2030 and net zero by 2070.

An optimistic estimation of India's total clean energy potential is about 4,000 TWh/annum. With present annual capacity of 10,000 TWh, total energy that can be made available will be 14,000 TWh/yr. This leads to a deficit of 6,000 TWh/yr clean/green energy by 2050. This works out to about 750 to 800 GWe (assuming the entire generation is assumed to be sourced from nuclear with high PLF). Today nuclear is just about 7.0 GWe. India has planned (optimistic) to produce 50 GWe of nuclear power by 2050. This still leaves a huge gap between demand and supply of energy by 2050.

As per our COP26 commitment, all our coal base power plants have to be phased out by 2050. That straight away amounts to starving the grid by about 220 GWe. The vacated fossil fuel thermal plants have sufficient area of land, infrastructure, connectivity, man-power, transport, water and large and small industries around the site. Typically, a coal plant needs 1.5 acres/MWe that includes area of ash ponds. Whereas, a nuclear power plant needs 0.7 acres/MWe land that includes the exclusive zone. The most ideal way to utilize the vacated sites by thermal plant is to build 100 MWe to 200 MWe nuclear plants with advanced engineering system to ensure inherently safe reactors. Today, SMRs are ideal choice to partially help in filling the gap of energy demand and also justify the precious land utilization.

2. Case for SMR

Typically on a site of 250mX250m area, 4X100MWe SMR can be installed. Several such abandoned coal plant sites, small and big are ideal locations for SMRs. When land availability and procurement are becoming difficult, utilizing such land works out to be win-win for all concerned. In that way the current search for land for ambitious plan of building larger nuclear plant totaling of 50 GWe by 2050 need not account for the land for SMRs.

One important issue in locating SMRs in the coal based plant vacated site is determining the size of emergency planning zone (EPZ). Generally, the size of the EPZs for nuclear power plants is defined by 1) a plume exposure pathway in EPZ area of about 10 miles in radius and 2) an ingestion pathway in EPZ area of about 50 miles in radius. The final EPZ size is the smallest distance at which the dose criteria, chosen to provide a level of protection that meets or exceeds the basis in NUREG-0396, are satisfied. These criteria essentially are a) total effective dose equivalent from the design basis source term is less than or equal to 1 rem; b) the total effective dose equivalent from less severe accidents (containment intact) is less than or equal to 1 rem; or c) a

substantial reduction in early health effects from more severe accidents (containment failure or bypass), i.e., an acute whole body dose less than 200 rem. In this regard, it is worth referring to the statement of USNRCs Advisory Committee on Reactor Safeguards after the recent review of Topical report (TR) of NuScale.[2]

"We also draw attention to the staff's conditions of use for the methodology in determining EPZ size. Practical applications of this methodology may produce a very small distance for the EPZ boundary. At close-in distances (less than one mile), timing and physical characteristics of the release (e.g., building wake effects, transport and deposition mechanisms, and/or chemical composition) may dominate rather than distance and dispersal.

We note that justifying a small EPZ will be different for non-light water reactors with little or no operating experience or sound estimates of the frequency of severe accidents. The uncertainty in severe accidents (e.g. external events) must be balanced against expected lower source terms and the passive and inherent safety features of the design. Engineering judgment may have to replace mechanistic analytic calculations in establishing the relevant accident phenomenology and system response."

In brief, there is an existing provision for a determination of the size of EPZs on a case-by-case basis for reactors with a power level of 250 MWth or less.

World-over the SMRs under development are rated around 100MWe with different configurations, operating parameters, fuel, containment etc. The most important safety requirement is to limit the dose to 1mSv/yr on the boundary of exclusive zone and 10 mSv (1 rem) at the boundary of EPZ. The current generation (GEN III+ and above) design of nuclear plants meet this criteria and looks like it is achievable.

From the public perception point of view, a design which ensures zero possibility of core meltdown is very important. This is possible with "walk away safe reactor". Such reactors will necessarily have all passive systems (for normal operation, emergency condition, control, Design Basis Accident, Beyond Design Basis Accident, air crash, tsunami, malevolent act of terror). In the case of an accident, the reactor cannot melt down, as all heat dissipates passively into the environment, no matter the scenario. SMR of 100 MWe is a do-able program in India with the current industrial infrastructure. The design of buoyancy driven natural circulation passive system for a 100 MWe SMR can also benefit in generating green hydrogen (400 kg/day/MWe) at an affordable cost and can produce several thousand m3/day (6000 m3/day) of clean drinking water from sea water.

3. NuScale Small Modular Reactor Design [3]

NuScale is around 70MWe SMR designed by US company whose design has evolved in the 15 to 20 yrs and today it has obtained preliminary approval from USNRC. Very shortly, it may obtain approval for commencement of construction. Construction time may be less than 5 yrs. As the design is integral type with natural circulation mode of cooling for normal operation and emergency operating condition, several experiments and model study has been carried out in a mission mode since 2007 to rejuvenate nuclear in USA. See Figure 1.

NuScale is fully passive and keeps the reactor safe for infinite time in case of severe accident thus ensuring public safety with no

environmental consequences. NuScale Power Plant does not require onsite or offsite AC electrical power to cope with design-basis events (DBEs). Safety systems are not reliant on AC or DC electrical power for actuation. The Reactor building is a seismic Category-I, reinforced concrete structure with design considerations for the effects of aircraft impact, environmental conditions, postulated design-basis accidents (internal and external), and design-basis threats. The reactor building also provides radiation protection to plant operations and maintenance personnel. The Decay Heat Removal System, is a closed-loop, two-phase natural circulation cooling system. Two trains of decay heat removal equipment are provided, one attached to each SG loop. See Figure 2.

The chief design features include,

- No alternating current (AC) or direct current (dc) power required for safe shutdown and cooling
- Compact helical coil SGs with reactor pressure on the outside of the tubes
- High-strength steel containment immersed in a pool of water
- Sub atmospheric containment pressure during normal operation
- Small core with a correspondingly small source term
- Comprehensive digital Instrumentation and Control (I&C) monitoring and control

The Nuclear Steam Supply System consists of a reactor core, two helical-coil SGs, and a pressurizer integrated within the RPV. The RPV is enclosed in a compact steel containment vessel (CNV) that sits in the reactor pool. The reactor core is located below the helical-coil SGs inside the RPV. Using natural circulation, the primary reactor coolant flow path is upward through the central hot leg riser, and then downward around the outside of the SG tubes with return flow to the bottom of the core through an annular downcomer. As the reactor coolant flows across the SG tubes, heat is transferred to the secondary-side fluid inside the SG tubes. Concurrently, as the secondary-side fluid progresses up through the inside of the SG tubes, it is heated, boiled, and superheated to produce high-pressure steam for the turbine generator unit.

The reactor core consists of 37 fuel assemblies and 16 control rod assemblies (CRAs). The fuel assembly design is similar to a standard 17x17 PWR fuel assembly with 24 guide tube locations for control rods and a central instrument tube. The fuel is uranium dioxide (UO2), with gadolinium oxide (Gd2O3) as a burnable absorber homogeneously mixed within the fuel in select rod locations. The uranium-235 enrichment is less than 4.95%.

The Reactor Pressure Vessel consists of a cylindrical steel vessel with an inside diameter of approximately 2.74 m and an overall height of approximately 17.68 m that is designed for an operating pressure of approximately 12.75 MPa. The upper and lower heads are torispherical, and the lower portion of the vessel has a flange to provide access for refuelling.

The CNV is a cylindrical steel pressure vessel housing the RPV, CRDMs, and associated NSSS piping and components. The CNV has an overall height of approximately 23.16 m and an outside diameter of approximately 4.57 m. The CNV is partially immersed in the reactor pool, which provides a passive heat sink for containment heat removal. The CNV is designed to withstand the external environment of the reactor pool, as well as the internal pressure and temperature of a design-basis accident.

The CNV is maintained at a vacuum under normal operating conditions. The benefits of maintaining a vacuum in the Containment Vessel include the following:

- Minimizes moisture content within the Containment Vessel
- Facilitates detection of leakage from the reactor coolant pressure boundary (RCPB)
- Eliminates convective heat transfer and, therefore, the need for RPV insulation, which reduces potential debris generated in the Containment Vessel
- Limits the initial amount of oxygen in containment (severe accident combustible gas consideration)
- The ECCS provides a passive means of decay heat removal in the event of a LOCA.

Figure 1. NuScale SMR [5]

On the sidelines of recently concluded G7 summit in Hiroshima, US, Japan, South Korea and UAE announced a public-private commitment of up to $275 million to support the advancement of NuScale Power's small modular reactor project in Romania. In addition, the US Export-Import Bank (EXIM) and US International Development Finance

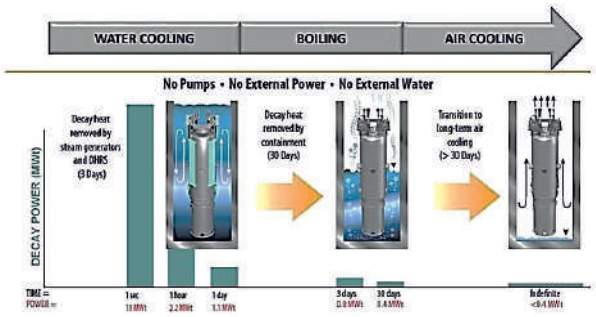

Figure 2. Decay Heat Removal System in NuScale SMR [6]

Corporation (DFC) issued letters of interest for potential support of up to $3 billion and $1 billion, respectively, for project deployment. [3] Some of the other SMRs in different stages of design, validation and approvals are

- NUWARD, EDF Consortium France. Integral
  type; 172 x 2 Mwe
- RITM-200, Russian High enrichment fuel
- SMR-160, Holtec International USA
- Rolls Royce, 300 MWE UK
- CAREM, 30 Mwe
- ACP-100, 125 MWe Forced circulation
- SMART 107 MWe Korean
- Additionally, today world over there may be
  many more number of designs of SMR.

4.0 Some issues in SMR

The challenges that must be addressed if SMRs are to become a game-changing scenario for nuclear energy globally are:

- A clear demonstration of the safety improvements and other benefits offered by SMRs
- A convincing case for competitive economics — both per kW installed and per kWh produced
- An improved international regulatory system enhancing licensing and

oversight while building public and political support
- Credible spent fuel management strategies
- Demand for SMRs (producing electricity, process heat or hydrogen) that is large enough to support 'production line' factory fabrication
- Political, financial, regulatory, and organizational support from governments for first of a kind SMRs.

Although SMRs are of smaller size meaning there is less waste heat to remove and much less radioactivity to manage during accident conditions but, probability of leakage is high. Leakage grows quadratically with decrease in core radius and reactor size. In large PWR the leakage of free neutron may be less than 3% whereas in 160 MWe PWR the leakage may be more than 7%.

Although the small size SMRs produce less radioactive waste to the burden of handling but, the specific volume of waste per unit of energy output is high. The increase is up to 35 times compared to a large conventional reactor. This is because SMRs do not reduce the generation of geochemically mobile fission products which are important dose contributors.

As SMRs use high fissile fuel, there is high probability of proliferation risk.

5. Step Ahead

DAE has rightly taken steps to initiate work on SMRs for power generation. Though, BARC has robust program for design, testing, integration, commissioning and deployment of small reactors for strategic applications, work on SMRs for grid connection will be a new initiative. However, the concept and expertise required for miniaturization of reactor systems for development of SMR is available. Even though the commitment is to increase the grid capacity with green nuclear power by 2050 is a tall challenge, SMRs can play an important role in terms of early manufacture and deployment of plants, low cost of power, low capital cost, low operating and fuel cost and more. When early deployment of SMR as local source of power starts happening, the success will go a long way in gaining public approval for having risen to the occasion of filling the gap of high power demand.

In this background, India must take urgent steps to give the necessary traction for development of Indian SMRs and funds to start of R&D activities wherever required. This would be the best way of tapping more than 2 decades of rich experience of compact reactor design.

6. References

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AI BASED TRANSIENT IDENTIFICATION AND OPERATOR DECISION SUPPORT SYSTEM FOR PHWRs (DIAGNOSTIC SYSTEM)

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Abstract

Artificial intelligence based transient identification and operator decision support system for 220MWe Pressurized Heavy Water Reactors (PHWRs) is developed and tested on a high speed computing facility at RSD, BARC. The transient identification module of diagnostic system employs Artificial Neural Network (ANN) model trained by a large database of plant transients simulated in-core (RELAP5) and containment (CONTRAN) thermal-hydraulic codes. The best-performing neural network model selection framework has been implemented in several stages. For the initial stages, a highly random selection approach is used and for the final stages the evolved robust and efficient network via recursive training scheme is used. The final ANN model has been obtained by creating an ensemble of the best-performing networks for identification of Loss of Coolant Accident (LOCA) and Main Steam Line Break (MSLB) scenarios. Blind validation exercises are carried out on the best-performing models to demonstrate thorough validation and testing of ANN models. The current version of Diagnostic system is capable of identifying a wide range of LOCA and MSLB scenarios in standard 220MWe PHWRs. Diagnostic system is built on a Remote Method Invocation (RMI) protocol concept for communication and integration with remote servers from the field (e.g. integration of Computerized Operator Information System (COIS)) for real-time transient identification.

Keywords: Operator decision support system, diagnostic system, neural networks, nuclear power plant.

1. Introduction

A Nuclear power plant (NPP) has several complex systems and components that are operated and monitored by human operators. Whenever a transient occurs in the plant (e.g. LOCA or MSLB), operators have to carry out several actions based on the available alarms/annunciations on the control panels. Based on on-the-spot diagnostic knowhow the operator has to take several corrective actions. In case of very early stages of possible severity of the transient, readings of the instruments may not always provide a clear indication of an anomaly to the operator. In order to assist operator during such circumstances and to facilitate timely corrective action, an Artificial Intelligence (AI) based technique is found profoundly useful. Hence, development of AI

based transient identification and operator decision support system (Diagnostic system) becomes important for accident management. The objective of the diagnostic system is to provide the operator suitable information about the impending transients like break in Primary Heat Transport (PHT) system, location and size of the break, etc. which could be potentially unsafe for the plant. Transient identification is a decision making process based on a number of process parameters /alarm states in order to avoid / minimize the consequences associated with the specific transients. Analysis of an event/transient involve determination of the consequence of a specified event such as LOCA in terms of fuel temperature, PHT storage tank level, containment temperature and pressure, etc. Diagnosis is identification of transients from the process signals selected from COIS. The event identification can be classified as a pattern recognition problem [1]. By properly selecting the plant parameters, a specific event can be identified by observing values / variations of the relevant parameters. For this purpose, around 45 COIS signals have been selected from respective Emergency Operating Procedures (EOPs) for identifying LOCA and MSLB scenarios in 220MWe standard PHWRs. The time-dependent transient data pertaining to the reactor core and the PHT has been generated using RELAP5 [2] and CONTRAN [3] thermal hydraulic codes. There are a number of linear and non-linear pattern recognition techniques available in the literature [4]. Among them ANN is one of the most widely employed machine learning techniques for solving complex problems which involve a large number of input signals and output events. General characteristic of a neural network is the ability to quickly recognize various conditions or states of a complex system once it has been fully trained. The final ANN model is then integrated with diagnostic system which provides most appropriate information about the evolving transient and assists the operator to take corrective actions to mitigate the accident condition well in time. The current version of the diagnostic system is able to identify 33 LOCA and 18 MSLB scenarios in 220MWe PHWRs.

2. Simulation of LOCA and MSLB

PHT system depressurizes rapidly upon the occurrence of large breaks in PHT system leading to LOCA thereby causing voids in the reactor core. This coolant voiding in the core causes positive reactivity addition and consequent power rise of reactor. Several trip signals will be activated such as high log rate, low PHT pressure, high neutron power, low PHT coolant flow and high reactor building pressure, etc. one after another in a short time. The sequence of trip actuation is largely dependent upon break location. Specifically, for break in Reactor Inlet Header (RIH), high log rate signal is the first signal followed by high neutron power, while for break in Reactor Outlet Header (ROH), low pressure signal is usually the first signal followed by high log rate. RELAP5 and CONTRAN thermal-hydraulic codes have been used to simulate 33 LOCA scenarios of pipe break in RIH and ROH, ranging from 20% to 200% double ended guillotine break.

MSLB scenario has also been modelled using RELAP5 and CONTRAN codes for simulating core and containment thermal-hydraulics for postulated pipe break in 400NB, 500NB and 700NB steam pipelines. Figure 1 show the

simulation carried out for 9 break locations. Transient data for two subsets each of 9 postulated cases with and without availability of Emergency Core Cooling System (ECCS) has been generated. Thus, a total of 18 cases have been analysed covering the possible break sizes, location and availability of ECCS. Transient results for COIS parameters in primary and secondary loops have been used in the development of ANN models.

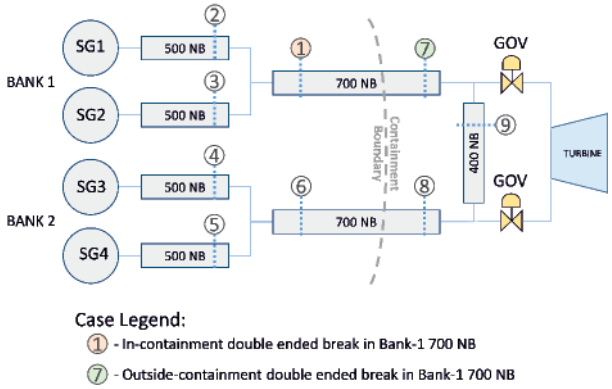

Figure 1: Schematic of main steam lines showing break locations

3. Model development

The transient identification can be classified as a pattern recognition problem for which neural network are found to be suitable. There is no pre-determined criterion for choosing a specific structure of neural network, and development of a best-performing network is based on the trial and error approach. The schematic diagram describing the model development approach is shown in Figure 2. Random sets of 1-hidden, 2-hidden, 3-hidden and 4-hidden layer neural networks are generated and a best-performing network from each category is selected based on the lowest Root Mean Square Error (RMSE). Depending on the individual network performance, a set of best-performing network will be selected for creating an aggregation model. If the performance of the aggregate model or any individual network is satisfactory then the model development process is terminated. This process is repeated until reasonably acceptable model is evolved.

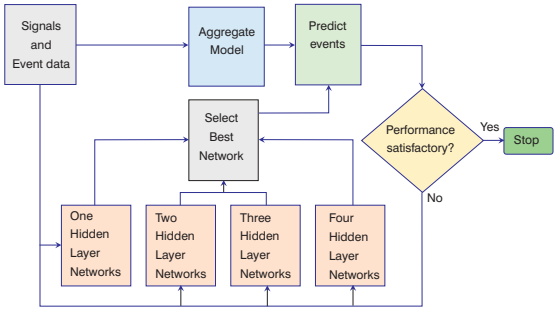

Figure 2: Schematic diagram of ANN model development approach

3.1 Training data

Artificial neural networks are widely known as data-driven techniques which rely on a large database of the input signals. In other words, ANNs require large amount of data to learn and recognize a particular input-output pattern. The data generated for simulation of transient events in RELAP5 and CONTRAN codes is randomly split into 70% training set, 15% validation set and 15% test set using the random subsampling with no replacement method. This creates a balanced training, validation and test sets which are non-overlapping subsets of the transient dataset. The advantage of using a balanced training set is that this ensures that the trained neural network make unbiased estimation of different break sizes in the test set. In contrast, a network trained on an imbalanced training set may tend to result in the break size target corresponding to the majority class of the training set which leads to poor generalization of the network. Validation check is performed during the training phase to control the over-

fitting. Event is identified by assigning a suitable event identification code in the input file. The final neural network model consists of 45 inputs and 4 output parameters for predicting LOCA and MSLB scenarios.

3.2 Performance of neural network

Levenberg-Marquardt Back-propagation algorithm is one of the most efficient and fast converging algorithms [5]. The algorithm is used for training the networks with the maximum epochs set to 1000 and the learning rate parameter set to 0.001. Various types of 1-hidden, 2-hidden, 3-hidden and 4-hidden neural networks are generated randomly by fixing the minimum and maximum neurons, and also fixing the total number of weights. The termination criterion is either fulfilling the validation checks or reaching to number of epochs or converging to the pre-set performance level (mean square error) which is set to 1e-4. From the performance evaluation study it is found that 3-hidden and 4-hidden layer networks perform well in predicting all the events over the entire dataset with RMSE less than 3. The prediction performance of all the networks for various scenarios of LOCA and MSLB on test data is shown in Figure 3. There are 33 LOCA and 18 MSLB predicted scenarios in Figure 3 from four different networks. Although the prediction from 1-hidden layer and 2-hidden layer networks for LOCA case is reasonable, their performance in predicting MSLB scenarios is not within the acceptable RMSE. The transient ID 20 to 200 on y-axis of Figure 3 represents scenarios of LOCA covering small break to large break LOCA, and the transient ID 400 to 700 represents scenarios of MSLB covering double ended guillotine breaks in 400NB, 500NB and 700NB lines. In order to improve the prediction rate further, a weighted-average aggregation model from these two networks has been created. It is observed from the results that the networks are able to capture the distinct feature from the training data to distinguish LOCA and MSLB scenarios which share many common process parameters.

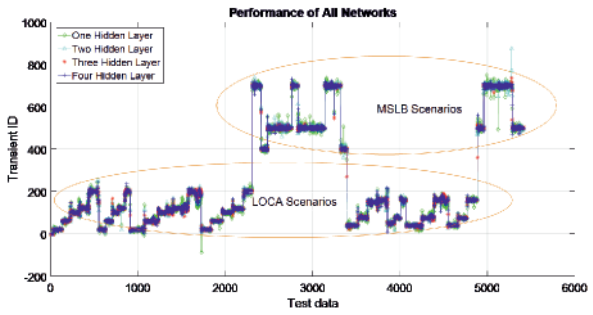

Figure 3: Performance of all networks

4. Operator Decision Support System

Diagnostic system employs AI model to predict the accident scenario well before the operator action can be anticipated. Continuous monitoring of COIS parameters by AI model enables Diagnostic system to predict the evolving accident scenarios in their early stage [6-7]. Whenever an event is detected, this system will display the type of the event, time at which the event has occurred and the relevant process parameters and their values at the time of initiation of the event. In addition, the trend of important process parameters during accident progression is displayed on the operator screen along with relevant EOPs. Currently, Diagnostic system has been set up on high speed distributed computing servers (Intel i7-2600 CPU @ 3.4GHz with 4GB RAM) for fast processing and real-time response. It has been successfully tested for real-time identification of LOCA and MSLB scenarios in 220MWe PHWRs. Figure 4 shows the screenshot operator screen of Diagnostic

system indicating the identified MSLB scenario inside the containment. The important process parameters and their values in red background colour indicate an abnormal reactor state. The complete details of the identified scenario are displayed at the bottom panel of the screen. Soon after the occurrence of transient process parameters show a deviation from their normal values. For example, in case of LOCA, the reactor outlet header pressure falls from its initial value of 87kg/sq.cm(g), PHT storage tank level drops from its initial normal level of 6m, containment pressure reaches set point of 0.018kg/sq.cm(g), etc. The real-time trending of these process parameters can be seen on the operator screen during the accident progression. Based on the evolving trend from a set of parameters this system identifies transient within a few seconds before implementation of operator actions. The accident scenario information panel (Figure 4, bottom panel) displays the actual predictions from ANN related to the type of the transient (e.g. LOCA or MSLB), location of the transient in headers, or inside or outside of the containment, and the status of ECCS actuation. Whenever a transient is identified this system will also display operator actions related to the identified event.

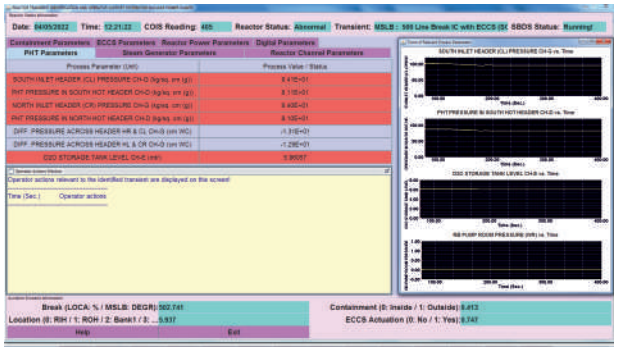

Figure 4: Screenshot of Diagnostic system showing 500NB line break inside containment with the availability of ECCS

5. Conclusions

Robust and efficient neural network model has been developed for identifying LOCA and MSLB scenarios in 220 MWe PHWRs. A three-tier learning scheme is followed in developing a single set efficient ANN model for predicting entire set of LOCA and MSLB transients for real-time application in plant by taking the signals from COIS. Blind case validation exercises have been carried out to test the performance of ANN model against generality check. Break size, break location (i.e. distinguishing break inside or outside containment; RIH or ROH, etc.), and also the status of ECCS actuation can be known from the tool. Around 33 LOCA and 18 MSLB scenarios can be predicted from the current version of the diagnostic system. The diagnostic system provides confidence to the operator for effectively identifying the transient and enabling him to handle the events and thus making management of the events with ease. Diagnostic system is a useful aid for training the plant operators. This AI based method will largely reduce dependence on human skill and help in reducing the human stress factor significantly. Training the ANN for detecting wide range of transients in a plant will truly make the tool robust and reliable which is the future scope of this research work.

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THE STORY OF URANIUM IN INDIA BY R.K. GARG AND D.S. SHUKLA

A Review by Dr. M. Ramanamurthi

'The story of Uranium in India', is the story of the forward march of the atomic energy programme of India initiated by the legendary Indian scientist Dr. Homi Jehangir Bhabha, who had the foresight to comprehend the huge potential of nuclear technology in various spheres, even though the technology was then still in its infancy. India today stands tall amongst a small comity of nations who have mastered the entire fuel cycle technology, thanks largely to the efforts of the pioneering and adventurous team of scientists and technologists who took on the challenge head on and succeeded in the objectives. The book captures the gamut of activities of this exhilarating journey, which was driven forward by the dedication, determination, ingenuity and innovative spirit of scientists and technologists of the Department of Atomic Energy (DAE). It recounts in great detail the progress of the Indian nuclear sector across all domains of the nuclear fuel cycle and is a rich repository of the history, legacy and achievements of India in the nuclear technology arena.

The authors, **Shri R.K. Garg and Shri D.S. Shukla** have been intimately associated with the development of several uranium related technologies and have made immense contributions towards research and development in India in this sphere. This book is a comprehensive and definitive account by these two protagonists and provides a ringside view of the story of uranium in India. It captures the technical essence of the journey, from the early days of trials, failures, struggles and tribulations, to the stage of eventual technological mastery. The extraordinary effort put in by the authors towards chronicling the monumental achievements of such a complex domain and creating an authentic record of events spanning over several decades is indeed commendable.

The **Introductory Chapter** speaks of uranium's primacy in nuclear energy, being the only naturally occurring element possessing the unique property of undergoing nuclear fission and releasing an enormous amount of energy when bombarded by neutrons. The discovery of uranium, its physical characteristics, and its historical importance as a resource, for use in nuclear weapons as well as for various peaceful purposes such as electricity generation is brought out, followed by the early development of nuclear power stations across the world. An account of the landmarks in the India story, such as the establishment of the Atomic Energy Commission in 1948, commissioning of research reactors, Apsara, Cirus and Dhruva and the commissioning of the first Indian power reactor at Tarapur forms the next segment. This is followed by a description of isotopes of uranium, fission reactions, potential use of other isotopes like U-233 and Pu-239 in specific reactor designs, distinctions between thermal reactors and fast reactors etc. The text brings out the need for high-purity uranium, either as metal or uranium dioxide (UO2), to fabricate fuel elements for reactors, and goes on to outline various steps involved in the nuclear fuel cycle, including exploration,

mining, milling, refining, enrichment, fabrication, reprocessing, and waste treatment. Finally, the chapter highlights the efforts of the Department of Atomic Energy to develop indigenous technologies for the entire uranium fuel cycle.

In the second chapter on **Uranium Exploration**, the authors provide detailed information about this foundational activity of the atomic energy programme, observing that prior to the discovery of nuclear fission, uranium exploration received little interest, but intensified globally thereafter due to the realisation of its strategic importance. The challenges faced in carrying out Uranium exploration due to the low abundance of uranium in the Earth's crust and its specific geological distribution have been brought out and the description of techniques used in exploration studies, such as remote sensing, geophysical surveys, and geochemical analysis, are described in detail. Mention is made of the "Red Book", a publication by the International Atomic Energy Agency (IAEA) which provides comprehensive information on uranium exploration and resources world wide. Classification of uranium deposits into different types based on geological certainty, cost of production, and conventional versus unconventional resources then follows. The chapter traces the journey from the early explorations in 1949 to the discoveries in 1990 in Telangana and subsequently in Meghalaya. It delves into the exploration efforts carried out by the Atomic Minerals Directorate for Exploration and Research (AMD) in India, highlighting the various geological domains and techniques used. The chapter concludes by summarizing the identified uranium resources in India, their distribution by deposit types, and the extensive work conducted by AMD in discovering and evaluating these resources over the past several decades.

The third chapter on **Uranium Mining and Milling** provides an overview of the mining and milling processes for uranium extraction, including alternative methods and the recovery of uranium as a by-product in different parts of the world, with a focus on developments in India. The text first describes the conventional practice of mining uranium ore deposit and taking it to a nearby mill, where it undergoes processes, such as crushing, grinding, leaching, filtration, concentration, and precipitation to obtain the final product called "Yellow Cake" or concentrate. Other methods such as open-cast, underground and heap leaching are also described in brief. Recovery of Uranium as a by-product during the production of gold, copper, or phosphoric acid as well as efforts to recover uranium from seawater, have been described with the observation that the low concentration of uranium makes them economically challenging. The text then discusses the developments in uranium mining and milling in India, starting with the establishment of the first uranium mill in the country, Jaduguda Uranium Mill Project (JUMP) in 1962. The progressive openings of subsequent mines and mills in different regions of India, including Turamdih, Tummalapalle, and others has been described followed by an account of the up gradation of mills at Jaduguda, Turamdih, and Tummalapalle to handle increased capacities. The chapter also mentions the attempts at recovery of uranium as a by-product in India, such as from copper tailings and during the processing of monazite and phosphoric acid.

The fourth chapter on **Uranium Refining and Conversion** provides an overview of the refining of uranium and the production of

uranium dioxide, uranium metal, uranium tetrafluoride, uranium hexafluoride and fluorine gas. The narrative begins with a description of the process for removing impurities from Yellow Cake, to make it suitable for use in nuclear applications. The impurity limits for uranium suitable for nuclear reactors are specified. The historical developments leading to the establishment of a Uranium Metal Plant (UMP) to produce nuclear-grade uranium for the Cirus Reactor are brought out with specific reference to the production of the first batch of nuclear-grade uranium metal being achieved in January 1959. The genesis of the processes and technology over time for production of better-grade Magnesium Diuranate (MDU) and the establishment of NFC at Hyderabad as an exclusive facility for refining and fuel fabrication is then elucidated. The principal refining process, alternate processes and equipment for refining uranium, production of uranium dioxide (UO2) and Uranium tetrafluoride (UF4) are also spelt out in detail. A discussion on the production of uranium metal, challenges faced in the use of calcium metal for uranium metal production using the calciothermic process due to its import dependence and import hurdles, and the development of the alternate route viz. the magnesiothermic reduction process have been detailed. The saga of the production of UF6 (uranium hexafluoride), which is an essential requirement for the isotopic separation of uranium, using a process based on fluorination of nuclear grade UF4 with elemental fluorine is elaborated upon. The chapter goes on to relate the challenges faced in finalising the process for elemental fluorine production required for this purpose. Emphasising upon its importance, the progress in a phased manner to increase cell capacities, keeping in view the safety and techno-economic considerations as well as the modifications and developments made to improve the performance, capacity, and safety of the cells has been brought out with great clarity.

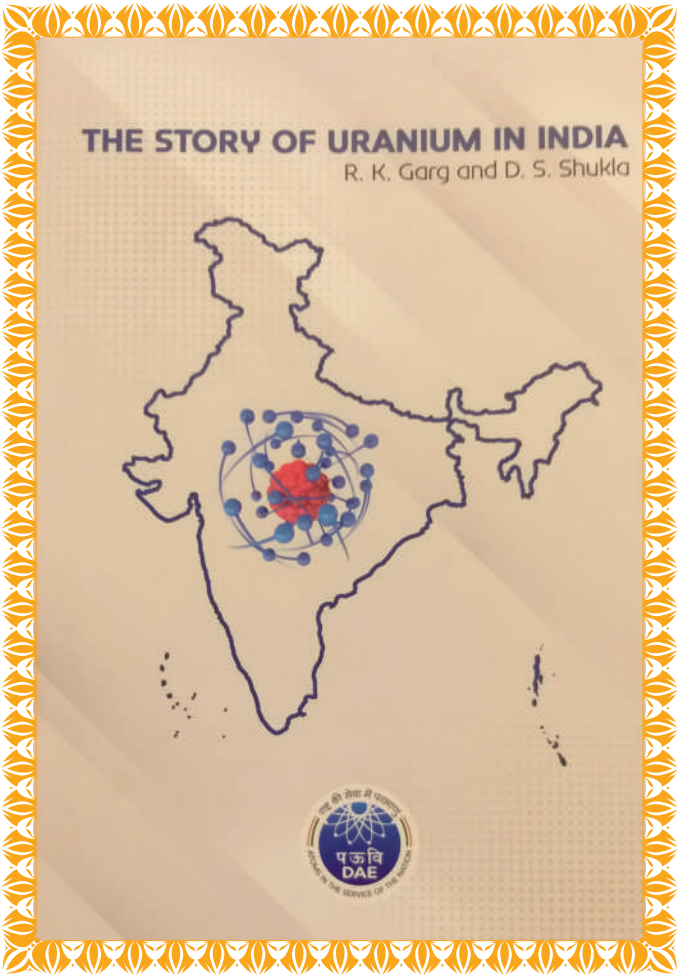
The fifth chapter on **Fuel Element Fabrication** describes processes for the manufacture of fuel elements used in different nuclear reactors. It provides details about the fabrication of Cirus fuel elements, Dhruva reactor fuel, and fuel for Pressurized Heavy Water Reactors (PHWR). The establishment of fuel fabrication facilities at the Nuclear Fuel Complex (NFC) in Hyderabad, to cater to the increasing fuel requirements of the Indian nuclear power program and its successes in the production of UO2 fuel assemblies, zircaloy components, and other reactor core components are elucidated with the observation that the process for UO2 powder production at NFC was similar to the process used in the Uranium Metal Plant. The expansions and improvements over the years to increase its production capacity and enhance fuel performance and introduction of measures such as changing wire-wrap to welded split spacer, installing vibro-sievers, using larger capacity furnaces, incorporating graphite coating of zircaloy tubes, and developing resistance welding techniques have been described.

The sixth chapter on **Reprocessing** brings out the importance of reprocessing of nuclear fuel in achieving several objectives, such as the recovery of valuable materials, conversion of radioactive waste, and utilization of thorium resources. The widely used Purex process involving steps such as decladding, dissolution, solvent extraction, purification, solvent reuse, and aqueous waste processing

are described and the details of Trombay Reprocessing Plant, Power Reactor Fuel Reprocessing Plant (PREFRE) at Tarapur, refurbishment of the Trombay plant to increase capacity to 100 tonnes per year, and the construction of Kalpakkam Reprocessing Plant (KARP) to augment reprocessing capacity near the Madras Atomic Power Station have been enunciated. The establishment of facilities such as Power Reactor Thoria Reprocessing Facility (PRTRF) for reprocessing of thorium-based fuels and fast reactor fuels, Reprocessing Development Laboratory (RDL) and the Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP), which are focused upon the unique challenges of reprocessing fast reactor fuel have been narrated. The chapter clearly establishes the fact that the construction and commissioning of these reprocessing facilities demonstrated India's mastery of the complex technology through indigenous efforts and that these advancements played a crucial role in India's nuclear power program, enabling the efficient use of resources and the safe management of nuclear waste.

The final chapter on Health, Safety and Waste Management is devoted to aspects of likely hazards such as radioactivity, nuclear criticality, chemical toxicity, as well as conventional hazards and the safety measures put in place to manage them. Waste management practices involved for safe disposal of radioactive wastes, with specific treatment and disposal methods based on the waste's characteristics have also been covered in detail. The priorities of the Indian nuclear energy sector towards the health and safety of its personnel, as well as the public and the environment has also been brought out by the authors. The genesis of safety-related programs and the formation of DAE Safety Review Committee and the Atomic Energy Regulatory Board (AERB) which were subsequently formed to review safety systems, set standards, and ensure compliance receive mention to emphasise upon the importance of this aspect. The formation of Health Physics Units (HPUs) and Environment Survey Laboratories (ESLs) to monitor safety measures and environmental impacts and ensure compliance with national regulations, such as the Environment Protection Act, has also been articulated, to highlight the importance placed by DAE upon health and safety, environmental protection, and waste management throughout the fuel cycle in compliance with national regulations and international best practices.

The value of the book has been aptly summed up by the Former Chairman, AEC, Shri K.N. Vyas in his foreword in the following manner- *"The need to bring out a single account covering all the developments in detail has always been felt by the nuclear community of India. This gap has now been filled by Shri R.K. Garg and Shri D.S. Shukla. I have found the book to be an invaluable source of information and knowledge on all aspects of the uranium story. The challenges faced and overcome the face of daunting obstacles should serve as source of pride to the members of the Indian nuclear community and inspire the young and the old alike to move forward with the conviction that any achievement is attainable with the right support, grit, determination, hard work and innovative spirit. I am confident that the book will find the pride of place on the bookshelves of scientists and technologists, not only from the nuclear fraternity, but from many other sectors in which cutting edge technologies play an important role in progress and development".*



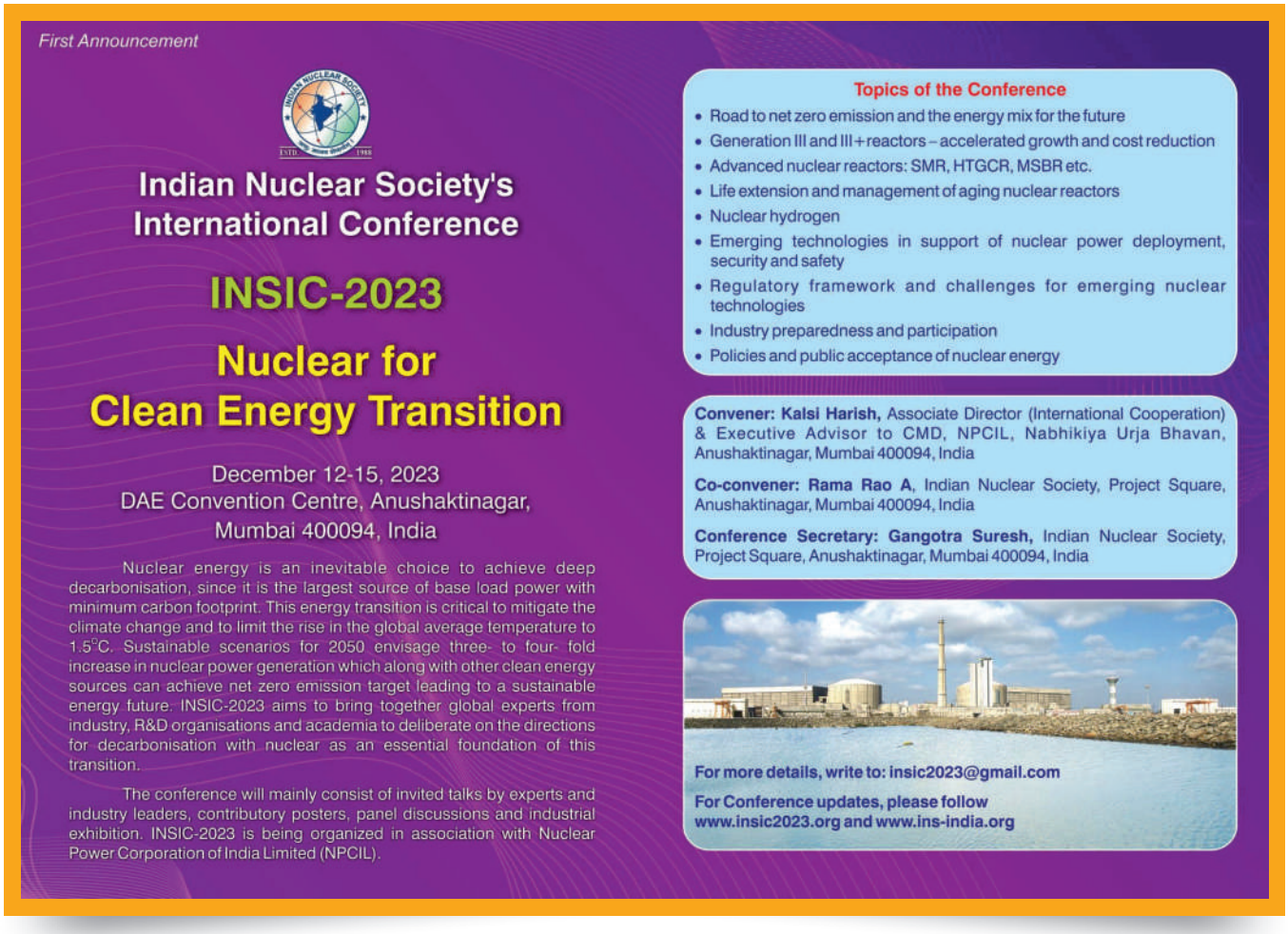
About the Authors

Shri R. K. Garg joined the Department of Atomic Energy in 1956 and his first assignment was as a team member for setting up and commissioning of the Uranium Metal Plant, which produced the first Uranium metal ingot of nuclear purity in January 1959. There after, his activities in the Bhabha Atomic Research Centre included the development of the process for Thorium Nitrate production by solvent extraction, development of the process and setting up of the plant for producing nuclear grade Zirconium Oxide for Zirconium Metal production at NFC Hyderabad and setting up the Rocket Propellent Plant at Trivandrum for the space programme. Both of these plants were commissioned in 1969-70. As Director,Chemical Engineering Group, he was associated with all steps of the nuclear fuel cycle including isotope separation and reprocessing. He was Chairman and Managing Director of Indian Rare Earths Ltd. for four years before superannuation in 1990. After superannuation, he served as Chairman of the Recruitment and Assessment Centre of Defence Research and Development Organisation (DRDO) for four years. He is actively engaged with industrial plant safety and environment protection and has been Chairman/Member of a number of committees of the Government of India as well as Pollution Control Boards and AERB. He was conferred the 'Homi Bhabha Lifetime Achievement Award- 2013' by the Indian Nuclear Society.

Shri D. S. Shukla completed his B.E (Chem) with Hons. from the University of Roorkee (now IIT, Roorkee) and is a recipient of the University Gold Medal. He joined the 13th batch of BARC Training School in 1969. He was the topper of the batch and was awarded the Homi Bhabha Medal. On completion of training, he joined the Chemical Engineering Division of Bhabha Atomic Research Centre. During the course of his illustrious career, he has been instrumental in evolving several novel concepts for the execution of critical departmental projects, as well as in detailing and operationalisation of various strategic projects of national importance. He has unique expertise in the field of uranium refining and has successfully led a team towards the indigenisation of complex technologies in this domain. He eventually rose to the position of Director, Chemical Engineering and Technology Group (ChE&TG), BARC, in which capacity, he guided research and development work in numerous fields, which included desalination of water and detritiation of heavy water. He superannuated from BARC in 2007 and continued to contribute to the activities of the Department as a Raja Ramanna Fellow from 2007 to 2015.

Published By:
Department of Atomic Energy

FIRST ANNOUNCEMENT OF INDIAN NUCLEAR SOCIETY'S INTERNATIONAL CONFERENCE 2023 (INSIC - 2023)



Nuclear energy is an inevitable choice to achieve deep decarbonisation, since it is the largest source of base load power with minimum carbon footprint. This energy transition is critical to mitigate the climate change and to limit the rise in the global average temperature to 1.50C. Sustainable scenarios for 2050 envisage three- to four- fold increase in nuclear power generation which along with other clean energy sources can achieve net zero emission target leading to a sustainable energy future.

INSIC-2023 aims to bring together global experts from industry, R&D organisations and academia to deliberate on the directions for decarbonisation with nuclear as an essential foundation of this transition.

The conference will mainly consist of invited talks by experts and industry leaders, contributory posters, panel discussions and industrial exhibition. INSIC2023 is being organized in association with Nuclear Power Corporation of India Limited (NPCIL).

IN LIVING MEMORY, BUT NOT KNOWN TO MANY!

Dr. M R Iyer

Many may not know that a 100 kW research reactor operated outside Trombay for about 3 months at New Delhi during 1960!

The TRIGA reactor manufactured by General Atomic Corp. USA was assembled, operated and finally decommissioned at the First World Agriculture Fair, New Delhi jointly by US AEC and AEET India.

This reactor was open for public viewing at the exhibition daily during the duration of the exhibition and used to supply radio-isotopes for research institutions around Delhi. The isotopes were processed in a special laboratory set up at the exhibition grounds by Isotope Division AEET (Late TS Murthy and team). The Neutron Physics Division, AEET (Late M Srinivasan and team) conducted several experiments of their design at the reactor. The Heath Physics Division, AEET provided health physics surveillance for the operations along with staff of US AEC who operated the reactor. The reactor was flashed daily once to about 15 MW for a few milliseconds with bright Cherernkov radiation glow by withdrawing the control rods leaving the reactor to shut down by itself using its negative temp. coefficient to the delight of the public.

That demonstrated how safe a nuclear reactor that can be operated in a public place is.

I had the opportunity to work as Heath physicist at the reactor for its duration including its decommissioning and shipping back the fuel to USA.

M R Iyer

NUCLEAR NEWS:
(April - June 2023)

Small & Micro Reactors, and Green Hydrogen

NuScale touts potential use of SMRs for steam production

NuScale Power says its small modular reactor (SMR) could be used to support the hard-to decarbonise industrial sector using superheated steam. The company said new research demonstrates the advanced capabilities of its SMRs for reducing emissions in industrial sectors, which is critical to meeting global climate goals.

NuScale touts potential use of SMRs for steam production : New Nuclear - World Nuclear News (world-nuclear-news.org)

Regulators support international collaboration on SMR technology

Members of the International Nuclear Regulators' Association (INRA) have released a joint statement in May, 2023 affirming their commitment to work together on generic design assessment and licensing of small modular reactor (SMR) technologies. INRA's nine member countries are Canada, France, Germany, Japan, the Republic of Korea, Spain, Sweden, the UK and the USA.

Regulators support international collaboration on SMR technology : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

BWRX-300 meets Polish safety requirements, says regulator

GE Hitachi Nuclear Energy's BWRX-300 small modular reactor (SMR) technology is compliant with Polish nuclear safety and radiological protection standards, the president of the National Atomic Energy Agency (Panstwowa Agencja Atomistyki, PAA) said in a general opinion.

BWRX-300 meets Polish safety requirements, says regulator : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

US microreactor prototype prepares for testing

The full-scale replica of the US Department of Energy's (DOE) MARVEL microreactor has been moved from Idaho to a facility in Pennsylvania where it will be used to test the behaviour of sodium-potassium and lead-bismuth coolants.

US microreactor prototype prepares for testing : New Nuclear - World Nuclear News (world-nuclear-news.org)

SMRs considered for Indonesian fertiliser plant

A collaboration between Danish and Indonesian companies will study the operational and regulatory conditions for constructing an ammonia production facility in Indonesia powered by Copenhagen Atomics' small and modular thorium molten salt reactors.

SMRs considered for Indonesian fertiliser plant : New Nuclear - World Nuclear News (world-nuclear-news.org)

Steel maker considers use of NuScale SMRs at its mills

NuScale Power has signed a memorandum of understanding (MoU) with North American steel manufacturer Nucor Corporation to explore the deployment of NuScale's VOYGR

small modular nuclear reactor (SMR) power plants at Nucor's scrap-based Electric Arc Furnace (EAF) steel mills.

Steel maker considers use of NuScale SMRs at its mills : New Nuclear - World Nuclear News (world-nuclear-news.org)

Korea considers deployment of NuScale SMR for hydrogen production

Private power generation company GS Energy has signed a memorandum of understanding (MoU) with Uljin County in North Gyeongsang Province, South Korea, to consider the use of NuScale Power's small modular reactor (SMR) technology to provide heat and power to the planned Uljin Nuclear Hydrogen National Industrial Complex.

Korea considers deployment of NuScale SMR for hydrogen production : New Nuclear - World Nuclear News (world-nuclear-news.org)

Westinghouse unveils AP300 small modular reactor

Westinghouse has launched in May 2023 what it calls a "game-changer" AP300 small modular reactor, a scaled-down version of its AP1000 reactor, with a goal for the first one to deliver power to the grid within a decade. It would be about 25% of the area of a football (soccer) pitch, with a target cost per unit of USD1 billion.

Westinghouse unveils AP300 small modular reactor : New Nuclear - World Nuclear News (world-nuclear-news.org)

Doosan starts forging components for NuScale SMR

South Korea's Doosan Enerbility, in first week of May, 2023, has begun the forging production process for the first module that will be deployed as part of a NuScale VOYGR-6 small modular reactor (SMR) power plant for the Carbon Free Power Project (CFPP) in the USA.

Doosan starts forging components for NuScale SMR : New Nuclear - World Nuclear News (world-nuclear-news.org)

NuScale in talks with the Philippines on SMR deployment

US small modular reactor (SMR) developer NuScale Power is interested in investing in the Philippines, the country's President Ferdinand "Bongbong" Marcos said during a five-day visit to the USA. He said NuScale plans to conduct a siting study in the Philippines.

NuScale in talks with the Philippines on SMR deployment : New Nuclear - World Nuclear News (world-nuclear-news.org)

OSGE seeks approval for SMRs at six Polish locations

Orlen Synthos Green Energy (OSGE) has submitted applications to Poland's Ministry of Climate for a decision-in-principle on the construction of power plants based on GE Hitachi Nuclear Energy's BWRX-300 small modular reactor (SMR) at six locations viz. Ostrołeka, Włocławek, Stawy Monowskie, Dabrowa Górnicza, Nowa Huta and Tarnobrzeg Special Economic Zone.

OSGE seeks approval for SMRs at six Polish locations : New Nuclear - World Nuclear News (world-nuclear-news.org)

Licence issued for Russia's first land-based SMR

Nuclear regulator Rostekhnadzor has granted a licence to build the country's first land-based small modular reactor (SMR), in the Republic of Sakha (also known as Yakutia) in Russia's Arctic north. Rosatom's SMR is a water-cooled RITM-200N reactor that has been adapted from the RITM-200 series used to power

the latest fleet of nuclear-powered icebreakers.The licence is to build the SMR in the Ust-Yansky district of Yakutia and Rosatom noted that the reactors had already proven their ability in Arctic conditions on the icebreakers.

Licence issued for Russia's first land-based SMR New Nuclear - World Nuclear News (world-nuclear-news.org)

Mass deployment of Holtec SMRs in Ukraine is part of accord's aims

Up to 20 Holtec SMR-160 plants will be built in Ukraine under a cooperation agreement signed between Holtec International and Ukrainian national nuclear operator Energoatom. The agreement calls for the first plant to begin supplying power by March 2029.

Mass deployment of Holtec SMRs in Ukraine is part of accord's aims : New Nuclear - World Nuclear News (world-nuclear-news.org)

MoU sees KAERI, Alberta cooperation on SMRs

Korea Atomic Energy Research Institute (KAERI) has signed a memorandum of understanding (MoU) with the Government of Alberta on April 19, 2023 to collaborate on the deployment of small modular reactor (SMR) technology - including the Korean-designed SMART reactor - in the Canadian province.

MoU sees KAERI, Alberta cooperation on SMRs : New Nuclear - World Nuclear News (world-nuclear-news.org)

Fresh cooperation agreement on SMR plan for Yakutia

Rosatom and the Corporation for the Development of the Far East and the Arctic have signed a cooperation agreement relating to the construction of a Russian small nuclear reactor power plant in the Republic of Sakha (also known as Yakutia).

Fresh cooperation agreement on SMR plan for Yakutia : New Nuclear - World Nuclear News (world-nuclear-news.org)

WENRA calls on industry to help expedite reactor design assessments

The Western European Nuclear Regulators Association (WENRA) has set out the steps that industry must take to ensure the timely, harmonised licensing of small modular reactor (SMR) and advanced modular reactor (AMR) designs in Europe. The organisation notes that an increasing number of countries are including SMRs and AMRs in their plans to meet decarbonisation targets. It said there is a "strong expectation from stakeholders on the national licensing processes to be completed expeditiously".

WENRA calls on industry to help expedite reactor design assessments : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

UK assessment of Rolls-Royce SMR design progresses

Rolls-Royce SMR Limited's 470 MWe small modular reactor (SMR) design has successfully completed Step 1 of the UK's Generic Design Assessment (GDA) process and progressed to the next phase.

UK assessment of Rolls-Royce SMR design progresses : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

Polish-US nuclear cooperation expands to USNC microreactors

Ultra Safe Nuclear Corporation, USA and the West Pomeranian University of Technology, Poland have signed an agreement to build a

nuclear energy research facility based on the former's Micro-Modular Reactor (MMR) technology.

Polish-US nuclear cooperation expands to USNC microreactors : New Nuclear - World Nuclear News (world-nuclear-news.org)

Virginia governor signs bills to support SMR development

Governor Virginia has signed into law two bills that will support ambitions for Virginia to include small modular reactors (SMRs) as part of an "all-of-the-above" energy plan released last year. Projects on SMR feasibility and supply chain have also received a share of USD8.1 million of grant awards announced by the governor.

Virginia governor signs bills to support SMR development : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

EDF creates new Nuward SMR subsidiary

France's EDF says that creating a wholly-owned subsidiary will enable the Nuward small modular reactor (SMR) to meet its "next key milestones" en route to achieving first nuclear concrete in 2030.

EDF creates new Nuward SMR subsidiary : Corporate - World Nuclear News (world-nuclear-news.org)

US-Korean partners to build SMR-powered hydrogen production facility

Ultra Safe Nuclear Corporation (USNC) of the USA has signed a memorandum of understanding (MoU) with South Korea's Hyundai Engineering and SK E&C in April 2023 o conduct joint research and development for the commercialisation of Hydrogen Micro Hubs over the next five years. The Hydrogen Micro Hub is a facility that produces hydrogen by applying a high-temperature electrolysis process of solid oxide electrolysis cells (SOEC) to the electricity and high-temperature steam generated by USNC's Micro-Modular Reactor (MMR).

US-Korean partners to build SMR-powered hydrogen production facility : Corporate - World Nuclear News (world-nuclear-news.org)

Rolls-Royce SMR puts case for producing hydrogen

UK-based Rolls-Royce SMR says a joint feasibility report produced with Sumitomo Corporation shows its small modular reactors have an advantage over other available sources for the production of hydrogen.

Rolls-Royce SMR puts case for producing hydrogen : Corporate - World Nuclear News (world-nuclear-news.org)

US companies move forward with green hydrogen projects

A coalition of companies including major utilities has applied for federal funding to build a green hydrogen network spanning six south-eastern states in the USA. Meanwhile, in Virginia, a property and project development company has secured a site where it plans to create a green energy centre with a green hydrogen hub and data centres powered by small modular reactors.

US companies move forward with green hydrogen projects : Energy & Environment - World Nuclear News (world-nuclear-news.org)

Role of Nuclear Energy / Public Acceptance

Record level of US support for nuclear continues

US public support for nuclear energy has remained at a record high level for the third consecutive year, according to the latest survey by Bisconti Research Inc. The results

show three quarters of the public favour nuclear energy, and about seven in ten support the construction of more nuclear power plants.

Record level of US support for nuclear continues : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

Nuclear Alliance calls for greater European support for nuclear

Nuclear could provide up to 150 GWe of generating capacity by 2050 in the European Union, according to a statement issued by 16 European countries following a meeting in Paris with European Commissioner for Energy Kadri Simson. The so-called Nuclear Alliance called on the European Commission to recognise nuclear energy in the EU's energy strategy and relevant policies.

Alliance calls for greater European support for nuclear : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

High support for advanced nuclear worldwide, survey finds

There is widespread public support for advanced nuclear energy technologies, according to a new, multinational survey of attitudes toward nuclear energy. The report is a collaborative effort by the non-governmental organisations ClearPath, Third Way, Potential Energy Coalition and RePlanet.

High support for advanced nuclear worldwide, survey finds : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

World events 'building momentum' for nuclear

Recent geopolitical events have focused world attention on the importance of energy security and the vital role that nuclear can play in providing clean, reliable energy. This is causing momentum to build in both nuclear generation plans and the supply chain to support it, said the keynote panellists at the World Nuclear Fuel Cycle 2023 (WNFC 2023) conference held during April 18 -20 in the Netherlands.

World events 'building momentum' for nuclear : Energy & Environment - World Nuclear News (world-nuclear-news.org)

Nuclear leaders issue call for action from G7

World Nuclear Association and nuclear trade associations from Canada, Japan, Europe, the UK and the USA have issued a declaration calling on G7 governments to support the long-term operation of existing nuclear power plants and to accelerate the deployment of new nuclear power plants.

Nuclear leaders issue call for action from G7 : Energy & Environment - World Nuclear News (world-nuclear-news.org)

UK looks to nuclear to bolster energy independence

The UK government is committed to a programme of new nuclear projects beyond Sizewell C, giving industry and investors the confidence they need to deliver projects at speed, according to a new policy paper. It describes nuclear as "the critical baseload of the future energy system". This policy paper sets out "ambitious plans to scale up affordable, clean, homegrown power and build thriving green industries in Britain boosting the country's energy security and independence and reducing household bills for the long-term and maintaining a world-leading position in achieving net-zero".

UK looks to nuclear to bolster energy independence : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

Canadian budget underlines government support for nuclear

Inclusion of nuclear in the clean energy investment tax credit and making it eligible for a range of other tax incentives show the Government of Canada's "clear and strong" support for nuclear's indispensable role in the clean energy transition, according to the Canadian Nuclear Association (CNA).

Canadian budget underlines government support for nuclear : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

Nuclear phase-out would increase pollution deaths, says study

The study - Nuclear power generation phase-outs redistribute US air quality and climate-related mortality risk - was published in Nature Energy on 10 April, 2023. As per the report, If the USA were to shut down its nuclear power plants, the pollution from the coal, gas, and oil that would be used to make up the generation shortfall would result in a worsening of air quality that could cause an additional 5200 pollution-related deaths over a single year.

Nuclear phase-out would increase pollution deaths, says study : Energy & Environment - World Nuclear News (world-nuclear-news.org)

Nuclear Co-operation, Collaboration, Partnerships

Orano signs partnership agreement with government of Niger

Orano, the multinational nuclear fuel cycle company with HQ in France has signed a partnership agreement in May, 2023 with government of Niger which covers the Imouraren project, the continued operation of the Somaïr mine, the remediation of the Cominak mine, and Orano's social commitment in Niger.

Orano signs partnership agreement with government of Niger : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

Expansion of US-Korean cooperation on SMRs

Agreements to cooperate on small modular reactors (SMRs) have been signed between South Korean and US companies during a visit by Korean President Yoon Suk-yeol to the USA in April, 2023. Doosan Enerbility and the Export-Import Bank of Korea (KEXIM) signed a memorandum of understanding (MoU) to cooperate with NuScale Power, while SK and Korea Hydro & Nuclear Power (KHNP) have agreed to collaborate

Expansion of US-Korean cooperation on SMRs : New Nuclear - World Nuclear News (world-nuclear-news.org)

Kazakhstan and IAEA agreement to strengthen nuclear cooperation

International Atomic Energy Agency (IAEA) and Kazakhstan signed a five year framework designed to "ensure closer interaction between the Agency and Kazakhstan in areas related to the development of nuclear power infrastructure, nuclear and radiation safety, food security and nuclear medicine".

Kazakhstan and IAEA agreement to strengthen nuclear cooperation : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

Hungary and Belarus agree nuclear energy cooperation

Hungary and Belarus have signed a memorandum of understanding (MoU) on cooperation relating to the projects in both countries for new Russian VVER-1200 nuclear reactors.

Hungary and Belarus agree nuclear energy cooperation : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

IAEA team completes follow-up Kazakh infrastructure review

Kazakhstan has made progress in implementing the recommendations of an International Atomic Energy Agency (IAEA) nuclear infrastructure review mission in 2016. The four-day Integrated Nuclear Infrastructure Review (INIR) mission was conducted at the government's request. Kazakhstan's Ministry of Energy has proposed the potential reintroduction of nuclear power to reduce the country's reliance on fossil fuels, diversify its energy mix and reduce CO2 emissions.

IAEA team completes follow-up Kazakh infrastructure review : New Nuclear - World Nuclear News (world-nuclear-news.org)

South Korea, UK enhance cooperation in nuclear energy

The UK and South Korea signed a joint declaration in April 2023 stating their agreement on the need for energy transition from fossil fuels to low-carbon power sources, prospects for South Korea's participation in new UK nuclear power plant projects and the two countries' exchanges and cooperation in offshore wind power, hydrogen and other clean energy areas.

South Korea, UK enhance cooperation in nuclear energy : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

New Constr. / Refurbishment/life Extension

Operating permit issued for Chinese molten salt reactor

The Shanghai Institute of Applied Physics (SINAP) of the Chinese Academy of Sciences has been granted an operating licence for the experimental TMSR-LF1 thorium-powered molten-salt reactor in June, 2023, construction of which started in Wuwei city, Gansu province, in September 2018.

Operating permit issued for Chinese molten salt reactor : New Nuclear - World Nuclear News (world-nuclear-news.org)

Second unit of Belarus nuclear plant connected to grid

The second unit of Belarus's first nuclear power plant has been connected to the power grid and delivered its first kilowatt-hours to the country's electricity system in May, 2023.

Second unit of Belarus nuclear plant connected to grid : New Nuclear - World Nuclear News (world-nuclear-news.org)

Construction begins of third unit at Egypt's El Dabaa nuclear power plant

First concrete has been poured into the foundation slab in May, 2023 marking the start of the main construction phase for unit 3 of the first Egyptian nuclear power at El Dabaa. Four units of the Russian VVER 1200 reactors are being set up by ROSATOM. Construction of first two units had started last year.

Construction begins of third unit at Egypt's El Dabaa nuclear power plant : New Nuclear - World Nuclear News (world-nuclear-news.org)

Dutch government allocates funding for nuclear programme

In its draft Climate Fund for 2024, the Dutch government has budgeted funds totalling

EUR320 million (USD352 million) for the development of nuclear energy. The funds will be used for the preparation of the operational extension of the existing Borssele nuclear power plant, the construction of two new large reactors, the development of small modular reactors (SMRs) and for nuclear skills development in the Netherlands.

Dutch government allocates funding for nuclear programme : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

TVO accepts Olkiluoto EPR ahead of commercial operation

Finnish utility Teollisuuden Voima Oyj (TVO) has issued an acceptance certificate to the Areva-Siemens consortium for the Olkiluoto 3 (OL3) EPR, which began regular electricity production on 16 April. It said the 1600 MWe reactor is scheduled to enter commercial operation on 1 May.

TVO accepts Olkiluoto EPR ahead of commercial operation : New Nuclear - World Nuclear News (world-nuclear-news.org)

Polish plans for large and small reactors progress

Polskie Elektrownie J drowe (PEJ) has submitted an application to Poland's Ministry of Climate for a decision-in-principle on the construction of the country's first large nuclear power plant. Meanwhile, Orlen Synthos Green Energy has announced seven potential sites for the country's first small modular reactors (SMRs).

Polish plans for large and small reactors progress : New Nuclear - World Nuclear News (world-nuclear-news.org)

Grid connection for Vogtle unit 3

Vogtle unit 3 began supplying its first electricity to the grid on 1 April, Georgia Power announced. The AP1000 reactor - the first new reactor to start up in the USA since 2016 - is scheduled to enter commercial operation by mid-year.

Grid connection for Vogtle unit 3 : New Nuclear - World Nuclear News (world-nuclear-news.org)

Two more Natrium units for coal-to-nuclear switching

US utility PacifiCorp has increased its ambition for using Natrium advanced reactors in the 2030s, adding two further units to its plans in addition to the demonstration unit already slated for a retiring coal power plant in Kemmerer, Wyoming.

Two more Natrium units for coal-to-nuclear switching : New Nuclear - World Nuclear News (world-nuclear-news.org)

New act in the USA aims to accelerate deployment of new nuclear

The Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2023, introduced to the US Senate by a bipartisan group, aims to support efforts to develop and deploy new nuclear technologies at home and abroad by measures such as regulatory support for advanced nuclear technology deployment and facilitating the repurposing of conventional energy sites.

Act aims to accelerate US deployment of new nuclear : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

First CGN Hualong One reactor enters commercial operation

Unit 3 of the Fangchenggang nuclear power plant in China's Guangxi Autonomous Region has entered commercial operation in March, 2023, China General Nuclear (CGN) announced. The unit is the first of two CGN-designed Hualong One (HPR1000) reactors at the site.

First CGN Hualong One reactor enters commercial operation : New Nuclear - World Nuclear News (world-nuclear-news.org)

Floating Nuclear Power Plant

Partnership formed to deploy Seaborg's Power Barge

Korea Hydro & Nuclear Power (KHNP), Samsung Heavy Industries (SHI) and Seaborg Technologies have established a consortium to develop floating nuclear power plants featuring Seaborg's compact molten salt reactor (CMSR) technology. The consortium's first project is expected to be a 200 MWe Power Barge.

Partnership formed to deploy Seaborg's Power Barge : New Nuclear - World Nuclear News (world-nuclear-news.org)

Russian export push for floating nuclear power plants

State nuclear power company Rosatom has signed an agreement with TSS Group to create a joint venture for the construction of a series of floating power units "with a capacity of at least 100 MWe and an assigned service life of up to 60 years for foreign markets and the subsequent sale of electricity from the floating power unit in the countries of presence".

Russian export push for floating nuclear power plants : New Nuclear - World Nuclear News (world-nuclear-news.org)

Nuclear Fuel, Fuel Material & other Nuclear Materials

Monju sodium to be processed in the UK

British nuclear services company Cavendish Nuclear has been awarded a contract by Japan Atomic Energy Agency (JAEA) IN May this year, to provide specialist capability in support of the decommissioning of the Monju prototype fast breeder reactor (PFR). The contract will see the design, construction, operation and ultimate dismantling of a new facility in the UK, for the treatment of sodium from Monju that will be recycled for industrial use.

Monju sodium to be processed in the UK : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

Five G7 countries in nuclear fuel agreement

The agreement by Canada, France, Japan, the UK and USA to leverage their civil nuclear power sectors to ensure a stable supply of nuclear fuel for existing and future reactors came as G7 climate, energy and environment ministers concluded a two-day meeting with a promise to accelerate the phase-out of fossil fuels.

Five G7 countries in nuclear fuel agreement : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

CNNC launches test platform to extract uranium from seawater

China National Nuclear Corporation (CNNC) has commissioned a seawater uranium extraction test platform, said to be the largest such test platform to be built in the South China Sea.

CNNC launches test platform to extract

uranium from seawater : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

USNC delivers TRISO particle fuel to NASA

Ultra Safe Nuclear Corporation (USNC) has delivered uranium nitride coated uranium oxycarbide tristructural isotropic (TRISO) fuel to NASA's Space Nuclear Power and Propulsion programme. The company says this demonstrates the "flexibility, precision and value" of its Pilot Fuel Manufacturing Facility (PFM).

USNC delivers TRISO particle fuel to NASA : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

Fuel Reprocessing / Radioactive Waste Mgmt.

France, Japan to cooperate on MOX fuel recycling studies

Japan's Federation of Electric Power Companies (FEPC) announced in May, 2023, it will work with France's Orano on demonstration research and development for the reprocessing of used mixed oxide (MOX) fuel.

France, Japan to cooperate on MOX fuel recycling studies : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

UK launches Nuclear Waste Services strategy

The Nuclear Waste Services strategy for the UK aims to make nuclear waste permanently safe, sooner. The strategy sets out key dates, such as capping starting on the Low Level Waste Repository in 2024-25, thermal treatment technologies developed as a proven technology by 2026-27 and decisions taken in 2026 on which communities will progress to detailed testing as part of the Geological Disposal Facility programme.

UK launches Nuclear Waste Services strategy : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

Slovenian used fuel storage facility commissioned

The first HI-STORM FW cask has been placed into the used fuel dry storage facility at the Krško nuclear power plant in Slovenia, officially marking the facility's commissioning, Holtec International announced in April, 2023.

Slovenian used fuel storage facility commissioned : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

Application submitted to extend Swedish repository

Sweden's radioactive waste management company Svensk Kärnbränslehantering AB (SKB) has submitted an application to the Radiation Safety Authority, SSM, to extend the existing SFR final repository for low and intermediate-level waste at Forsmark. The company plans to expand the repository to almost three times its current size in order to receive demolition waste from decommissioned Swedish nuclear power plants.

Application submitted to extend Swedish repository : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

Regulation, Safety, Security, Safeguard

NRC approves use of Framatome codes in advanced nuclear fuel development

Framatome received approval from the US Nuclear Regulatory Commission (NRC) to apply the company's suite of Advanced Codes and Methods to operating conditions

with uranium-235 enrichments above the industry standard of 5%. The NRC decision is an important milestone for the company's advanced fuel development efforts targeting improved fuel utilisation for nuclear plant operators and systematic improvements for safety and plant economics.

NRC approves use of Framatome codes in advanced nuclear fuel development : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

Research Reactors, Isotope Production/Processing

New Czech research reactor commissioned

The VR-2 research reactor, construction of which began last year, has entered operation in the first week of June 2023at the Faculty of Nuclear Sciences and Physical Engineering (FNSPE) at the Czech Technical University (CTU) in Prague. The reactor will mainly be used for teaching nuclear engineering students.

New Czech research reactor commissioned : New Nuclear - World Nuclear News (world-nuclear-news.org)

Kazakh research reactor recommissioned after fuel conversion

The IVG.1M research reactor in Kurchatov, Kazakhstan, is ready to resume experiments following the completion of a project to convert it from using highly-enriched uranium (HEU) fuel to low-enriched uranium (LEU) fuel, the country's National Nuclear Centre (NNC) announced in May 2023.

Kazakh research reactor recommissioned after fuel conversion : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

Preparatory construction begins for Pallas research reactor

Work has begun to build the foundations for the Pallas research reactor in Petten, the Netherlands, which will replace the existing High Flux Reactor (HFR). However, the Dutch government is yet to make a final decision on constructing the reactor.

Preparatory construction begins for Pallas research reactor : New Nuclear - World Nuclear News (world-nuclear-news.org)

Korea starts construction of new research reactor

The first concrete has been poured for the Kijang Research Reactor (KJRR) at the Radiology Science Industrial Complex in Gijang-gun, Busan, the Korea Atomic Energy Research Institute (KAERI) announced in May 2023.

Korea starts construction of new research reactor : New Nuclear - World Nuclear News (world-nuclear-news.org)

Fuel innovation means research reactor can transition from HEU

Framatome has completed the development of the main component of innovative monolithic molybdenum-uranium (U-Mo) fuel for the FRM II research reactor at the Technical University of Munich (TUM).

Fuel innovation means research reactor can transition from HEU : Uranium & Fuel - World Nuclear News (world-nuclear-news.org)

New facility streamlines isotope production at US lab

Brookhaven National Laboratory (BNL) has announced in April 2023, the shipment of the first actinium-225 (Ac-255) to be produced in a newly refurbished hot cell laboratory at the US Department of Energy's (DOE) lab. The

new facilities will streamline production and shipment of the rare radioisotope for the development of new cancer treatments. Ac-225 is an extremely rare alpha-emitting radioisotope that can be used in targeted alpha therapy.

New facility streamlines isotope production at US lab : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

Progress in production of isotopes from US legacy waste

Some 75-100 times more doses of next generation alpha targeted therapy treatments will be available annually worldwide, compared with today, through a project to produce isotopes from legacy nuclear material at the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL), the project partners say. Since 2003, Isotek has been responsible for safely and securely overseeing the inventory of uranium-233 and preparing its removal from ORNL. Since then, employees have transferred and dispositioned about half of the inventory. The remaining inventory requires processing and downblending prior to disposal, which began in October 2019. Isotek Systems (a subsidiary of Atkins Nuclear Secured), TerraPower and the DOE entered a public-private partnership in 2018. Through this partnership, Isotek is extracting the rare medical isotope thorium-229 for TerraPower Isotopes, a subsidiary of TerraPower, to advance promising cancer treatment research.

Progress in production of isotopes from US legacy waste : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

New isotope-producing research reactor for Missouri

The University of Missouri has launched an initiative to build a new, larger research reactor, NextGen MURR. The university's existing MU Research Reactor (MURR) - in operation for more than half a century - is the highest-powered university research reactor in the USA and is currently the country's only producer of certain medical radioisotopes.

New isotope-producing research reactor for Missouri : New Nuclear - World Nuclear News (world-nuclear-news.org)

Mo-99 production reaches non-proliferation milestone

All major global molybdenum-99 (Mo-99) production facilities are now using low-enriched uranium (LEU) targets instead of proliferation-sensitive highly-enriched uranium (HEU) following the completion of work to convert Belgium's National Institute of Radioelements (IRE) medical isotope production facility.

Mo-99 production reaches non-proliferation milestone : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

The critical production of cobalt-60 in nuclear reactors

In addition to the provision of clean energy, the production of isotopes in support of health care remains a highly positive contribution of the nuclear industry to societal wellbeing.The production of cobalt-60 is critical to healthcare and, with demand soaring, the challenge is to expand supply, writes Martin Comben from the International Irradiation Association.

Viewpoint: The critical production of cobalt-60 in nuclear reactors : Perspectives - World

Nuclear News (world-nuclear-news.org)

Miscellaneous

Nuclear-powered 'flashlight' to be developed for lunar studies

An X-ray "flashlight" which would use an energy source based on Ultra Safe Nuclear Corporation's (USNC) EmberCore nuclear chargeable ceramic technology to map the lunar surface has been selected for early-stage funding in the NASA Innovative Advanced Concepts (NIAC) programme.The "flashlight" will use a beam of X-rays and gamma rays that can travel over many kilometres, interact with the ground and then bounce back towards a sensor. The signal that is returned to the sensor provides an "elemental fingerprint" of information about the lunar surface and what lies beneath it. Backscattered gamma rays could be used to infer the presence of substances such as water.

Nuclear-powered 'flashlight' to be developed for lunar studies : New Nuclear - World Nuclear News (world-nuclear-news.org)

New 3D printer will benefit nuclear industry, says Rosatom

The largest 3D printer of its type in Russia has been unveiled by Rusatom - Additive Technologies (RusAT), with claims it will "allow printing of large-sized parts of nuclear reactors" and reduce costs and manufacturing time.

New 3D printer will benefit nuclear industry, says Rosatom : Corporate - World Nuclear News (world-nuclear-news.org)

Emergency-use robot trialled at Sellafield

A remotely-operated rescue robot capable of withstanding hazardous environments has been evaluated at the UK's Sellafield nuclear site. Designed and manufactured by British engineering firm Forth, the Rescue Robot will make emergency jobs across UK nuclear plants "significantly safer and more cost effective".

Emergency-use robot trialled at Sellafield : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

New North American nuclear training programme launched

Westinghouse Electric Company, Spanish engineering firm Tecnatom and US consulting and training services provider Accelerant Solutions have agreed to form the Nuclear Excellence Academy (NEXA), a nuclear training programme for utilities in the USA and Canada.

New North American nuclear training programme launched : Corporate - World Nuclear News (world-nuclear-news.org)

Tributes paid as Germany's last nuclear plants close

The operators of the last three nuclear power plants in Germany have marked their closures by saluting their operational records and contribution to providing low-carbon energy in the country for more than three decades.

Tributes paid as Germany's last nuclear plants close : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

The end of Germany’s nuclear power

With the last three operating nuclear power reactors in Germany being permanently shut down on April 15, 2023, the Germany’s Nuclear Power Era comes to an end.

A guide: The end of Germany’s nuclear power : Nuclear Policies - World Nuclear News (world-nuclear-news.org)

Extract energy from used nuclear fuel, says environmental group

If existing inventories of used nuclear fuel were recycled and repurposed as fuel for advanced fast reactors, it could generate zero-carbon electricity for Europe for up to 1000 years, according to international environmental campaign group RePlanet. In its new report - What a waste: How fast-fission power can provide clean energy from nuclear waste - RePlanet says Europe's nuclear power reactors "have a long history of safe use, and have provided prodigious quantities of clean electricity for decades". However, it notes that they use less than 1% of the actual energy potential in the natural uranium used to make their fuel and irradiated fuel assemblies removed from reactors are considered 'nuclear waste'.

Extract energy from used nuclear fuel, says environmental group : Waste & Recycling - World Nuclear News (world-nuclear-news.org)

Nuclear Fusion

US awards USD46 million funding, aiming for fusion pilot plant

The Department of Energy of USA is sharing USD46 million funding from the Milestone-based Fusion Development Program among eight companies, with the aim that "within five to 10 years" they "will resolve scientific and technological challenges to create designs for a fusion pilot plant".

US awards USD46 million funding, aiming for fusion pilot plant : New Nuclear - World Nuclear News (world-nuclear-news.org)

Jacobs to design remotely-operated tools for ITER

Jacobs with HQ at Dallas in Texas, USA has been awarded a contract to design and engineer maintenance systems for the International Thermonuclear Experimental Reactor (ITER) fusion project.

Jacobs to design remotely-operated tools for ITER : Corporate - World Nuclear News (world-nuclear-news.org)

Fluor and Longview MoU for laser fusion development

Fluor Corporation has signed a memorandum of understanding (MoU) with Longview Fusion Energy Systems to be its engineering and construction partner in designing and planning laser fusion energy commercialisation. The MoU will see Fluor using its experience in developing and constructing large-scale facilities to provide the preliminary design and engineering support for the development of Longview's proposed fusion plant.

Fluor and Longview MoU for laser fusion development : New Nuclear - World Nuclear News (world-nuclear-news.org)

NRC starts work on regulatory framework for fusion

The US Nuclear Regulatory Commission (NRC) will base its regulatory framework for fusion energy systems on its existing process for licensing the use of byproduct materials.

NRC starts work on regulatory framework for fusion : Regulation & Safety - World Nuclear News (world-nuclear-news.org)

Chinese and German milestones in fusion research

A Chinese tokamak device has set a new world record for a steady-state high-constraint mode plasma operation and German researchers have discovered a way to build smaller and cheaper fusion reactors.

Meanwhile a US Government Accountability Office report on achieving commercial fusion cautions that several challenges must still be overcome.

Chinese and German milestones in fusion research : New Nuclear - World Nuclear News (world-nuclear-news.org)

UK-US partnership for nuclear fusion rockets

UK clean space propulsion systems and services company Pulsar Fusion has formed a partnership with USA-based Princeton Satellite Systems to use artificial intelligence (AI) to design a hyper-fast space rocket capable of reaching Mars in only 30 days.

UK-US partnership for nuclear fusion rockets : New Nuclear - World Nuclear News (world-nuclear-news.org)

CNL, Kyoto Fusioneering join forces for fusion tech development

Canadian Nuclear Laboratories (CNL) has signed a memorandum of understanding (MoU) with Japanese company Kyoto Fusioneering Ltd (KF) to partner on the delivery of technical services to support the growing international fusion reactor market, with a key focus on testing related to tritium.

CNL, Kyoto Fusioneering join forces for fusion tech development : New Nuclear - World Nuclear News (world-nuclear-news.org)

British-Korean partnership for fusion robotics

The UK Atomic Energy Authority (UKAEA) and the Korea Institute of Fusion Energy (KFE) have signed a memorandum of understanding (MoU) to cooperate in research and development for remote handling and the maintenance of future fusion power plants.

British-Korean partnership for fusion robotics : New Nuclear - World Nuclear News (world-nuclear-news.org)

A REPORT ON SMRs RELEASED BY NITI AAYOG

A Report on the role of small modular reactors in the energy transition, authored by NITI Aayog with Department of Atomic Energy (DAE), Government of India and Tata Consulting Engineers Limited (TCE) was released at **the International Seminar on the Role of Small Modular Reactors in the Energy Transition** held as part of **the 3rd Energy Transitions Working Group Meeting** held in Mumbai during May 16-17 under India's G20 presidency. According to the report, SMRs have emerged as preferred nuclear energy options when compared to large reactors because they require a low inventory of nuclear material per reactor, quick fabrication through standardisation, fast realisation, feasibility of deployment at difficult sites, and phased capital expenditure by adding successive batches of SMR modules. The report looks at the role of SMRs in the energy transition, the status of technology development, readiness of supply chains, initiatives to harmonise SMR regulation and the international licensing process, and preparation for international safeguards, as well as the need to de-risk SMR projects to attract investment from private players.

NTPC AND NPCIL SIGN AGREEMENT FOR JOINT DEVELOPMENT OF NPPs

NTPC Ltd. signed a Supplementary Joint Venture (JV) Agreement with Nuclear Power Corporation of India Ltd. (NPCIL) in New Delhi on May 1, 2023 for development of Nuclear Power Projects. The agreement was signed by Mr. Ujjwal Kanti Bhattacharya, Director Projects, NTPC Ltd. and Mr. Ranjay Sharan, Director Projects, NPCIL in the presence of Shri R.K. Singh, Minister of Power, New & Renewable Energy, Shri K.N. Vyas, Secretary DAE & Chairman Atomic Energy Commission, Shri Alok Kumar, Secretary, Ministry of Power, Shri Gurdeep Singh, CMD NTPC, Shri B C Pathak, CMD NPCIL and senior officials of Ministry of Power and Department of Atomic Energy.

This Supplementary Joint Venture Agreement marks a pivotal step for NTPC Ltd. and NPCIL to collaborate and cooperate in the field of development of Nuclear Power projects which shall help the country in meeting its Clean Energy Commitments to achieve net zero emission target by 2070.

Initially, the JV company shall develop two projects - Chutka Madhya Pradesh Atomic Power Project (2x700 MW PHWRs) and Mahi Banswara Rajasthan Atomic Power Project (4x700 MW PHWRs).

PHOTO GALLERY

Dr. B N Jagatap, President INS, felicitating Shri Dinesh Kumar Shukla, Chairman AERB, who delivered a talk at on his perspectives on the "Safety-Security Interface at Nuclear Power Plants" at the INS Seminar on June 03, 2023.

The views and opinions expressed by the authors may not necessarily be that of INS.
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