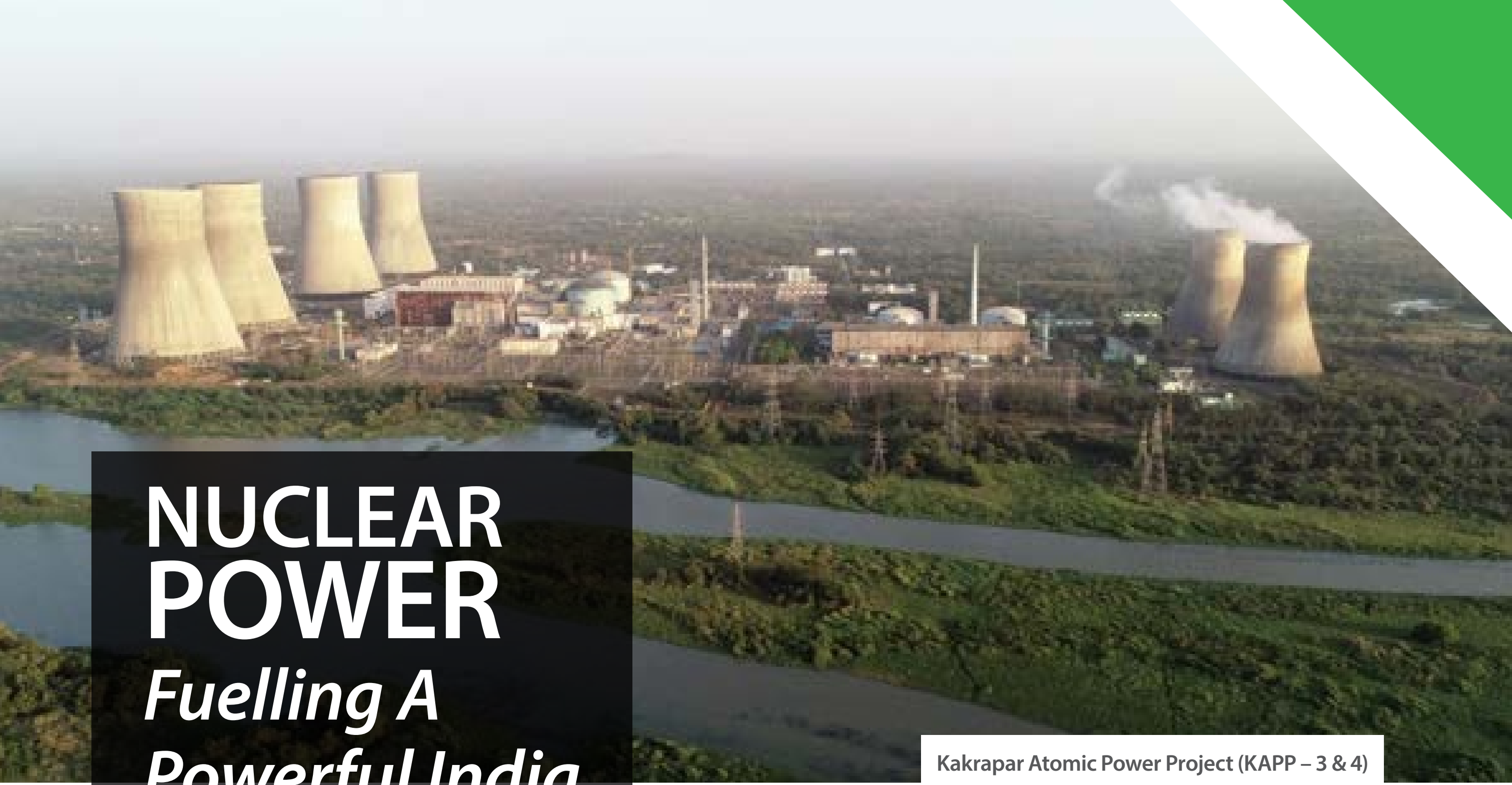


NUCLEAR POWER
Fuelling A Powerful India

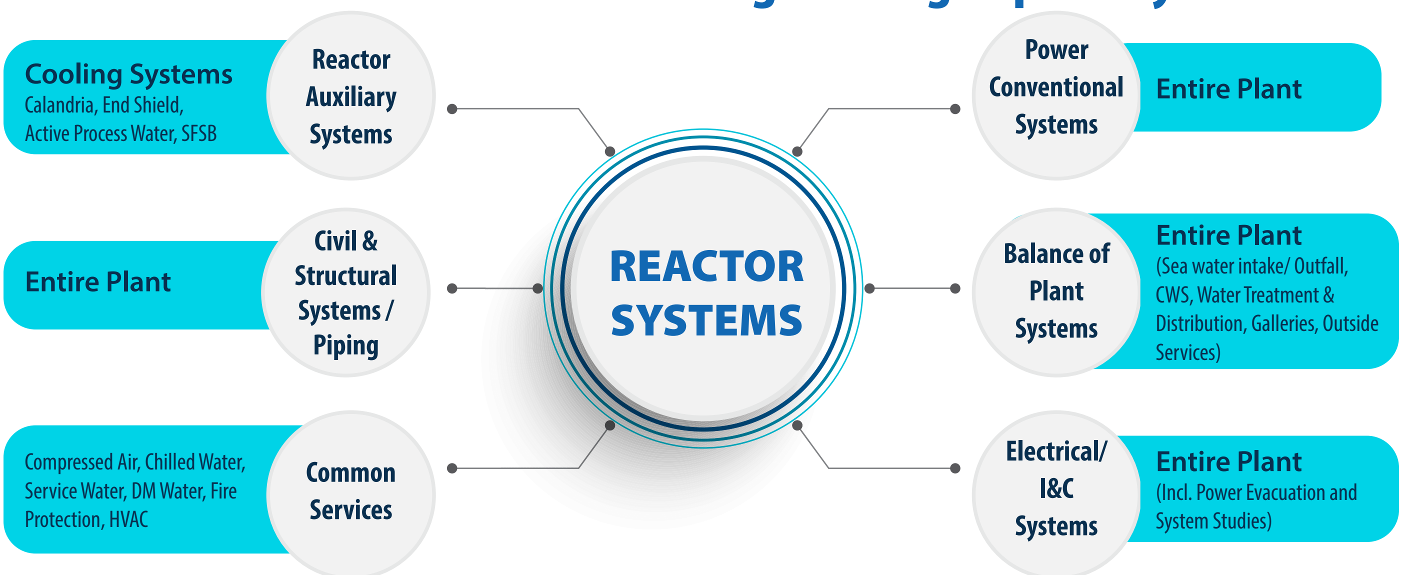
Kakrapar Atomic Power Project (KAPP – 3 & 4)

Building "Brand India" on a global stage

Nuclear power generation plays a vital role in India's energy security and energy transition aspirations. India started its Nuclear energy program soon after independence by setting up the Indian Atomic Energy Commission in 1948 (Today's Department of Atomic Energy (DAE)), pursuing relentlessly to empower India with high technology and advanced scientific research in the nuclear field.
DAE has an ambitious plan, which puts India on a high pedestal in the global arena.

TCE has been continuously working for DAE and its various units for the past four decades in engineering nuclear power projects and associated infrastructure facilities. TCE's rich engineering experience covers complete plant engineering for nuclear power projects with boiling water reactors, pressurised heavy water reactors and fast breeder reactors (Fig.1). Also, TCE has extensive experience and capability to engineer nuclear fuel processing, fuel fabrication and waste management facilities.

Nuclear Power Plants - Engineering Capability



Special Capabilities

1. Integrated 3D/4D Engineering 2. Fire Hazard Anaysis 3. Plant Layout Studies 4. Advance Analysis (FEA/CFD/Blast Analysis) 5. Special component Design (Fuelling machine) 6. Industrial Automation & Remote Handling

Fig. 1: TCE's Nuclear Engineering Capability

TCE has achieved 85% market share in engineering services in the nuclear sector, thus becoming a trusted partner in implementing projects of national importance and strategic in nature.

Nuclear Power in India – Present Scenario

Nuclear power generation's total installed capacity in our country stands at 6780 MW as of December 2020, which is about 2% of the total installed power generation capacity. In terms of electricity generated, all operating nuclear plants added nearly 46 billion units of electricity to our national grid in FY20, which accounted for a little more than 3% of total electricity generated in our country in the corresponding period.

Presently, 22 nuclear power reactors are operating in India, and many units are under various stages of implementation. Government of India has an ambitious plan of tripling the installed nuclear power generation capacity in the next ten years. The Units No 1 & 2 in Tarapur Atomic Power Station (TAPS) had completed ***50 years of safe operation*** as of May 2019. Unit No. 1 of Kaiga Atomic Power Station (KAPS) had ***set a world record of 962 days of continuous operation.*** These benchmark performances reaffirm our highest safety standards of Nuclear power plant operation.

India's Long-Term Approach

India has an advantage in terms of the availability of nuclear fuel resource. Though the availability of Uranium is limited, we have an extensive resource of thorium. Kerala and Orissa's beach sands have rich monazite reserves, which contains about 8 – 10% thorium. Thorium can be used to produce nuclear energy, but not directly due to its physical properties. Thorium must be converted to U233 in a nuclear reactor so that it can be used as fuel.

India's nuclear power program (three-stage approach) is a long-term vision to meet our country's energy needs for several centuries, duly addressing the climate change challenges.

The three-stage process multiplies power generation potential by expanding the nuclear fuel base.

- We adopt pressurised heavy water reactors (PHWRs) with natural uranium 235 (U235) as fuel and heavy water as moderator & coolant in the first stage.
- In the second stage, we will adopt fast breeder reactors (FBRs) with depleted Uranium and plutonium obtained from recycled spent fuel from the stage 1 reactors with thorium as a blanket produce Uranium 233 (U233).
- In the third stage, we will be using breeder reactors (BRs) with U233 as fuel produced from stage 2 reactors. The power generation potential is enormously high and will be sustainable for many centuries.

A large amount of work has been carried out on several aspects of thorium fuel cycle viz. mining and extraction, fuel fabrication, evaluation of its properties, reprocessing and recycling.

Nuclear Power Projects under implementation

The indigenously designed 700 MW Pressurised Heavy Water Reactor (PHWR) is our nuclear power generation fleet's work-horse. The following projects with a cumulative capacity of 8200 MW are under various stages of implementation. Unit No. 3 of KAPP achieved its criticality in July 2020, and other units in KAPP and RAPP would be achieving criticality in a phased manner.

The construction work is in advanced stage in the Kudankulam project, and the first pour of concrete (FPC) has been achieved in GHAVP project recently.

Project	Reactor Type	Plant Capacity
Kakrapar Atomic Power Project (KAPP-3&4)	PHWR	2 x 700 MW
Rajasthan Atomic Power Project (RAPP-7&8)	PHWR	2 x 700 MW
Kudankulam Nuclear Power Project (KKNPP-3&4)	LWR	2 x 1000 MW
Gorakhpur Haryana Anu Vidyut Pariyojana (GHAVP-1&2)	PHWR	2 x 700 MW
Kudankulam Nuclear Power Project (KKNPP-5&6)	LWR	2 x 1000 MW

Fleet Mode Implementation Shifting gears

To achieve a quantum leap in implementing nuclear power projects, NPCIL has announced fleet mode implementation of 10 numbers of 700 MW PHWR reactors (a fully indigenously developed design), thus enabling further addition of 7000 MW of power generation capacity within next ten years. Following are the proposed projects under fleet-mode implementation.

Project	Reactor Type	Plant Capacity
Kaiga Atomic Power Project (Kaiga-5&6)	PHWR	2 x 700 MW
Gorakhpur Haryana Anu Vidyut Pariyojana (GHAVP-3&4)	PHWR	2 x 700 MW
Chutka Nuclear Power Project (Chutka-1 &2)	PHWR	2 x 700 MW
Mahi Banswara Nuclear Power Project (Mahi 1&2)	PHWR	2 x 700 MW
Mahi Banswara Nuclear Power Project (Mahi 3 & 4)	PHWR	2 x 700 MW

Next stage reactors

Indian Government has set up a company, ***Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI)*** to construct and commission fast breeder reactors in our country. ***BHAVINI is presently building 500MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam.*** The PFBR is the fore-runner for future installations of Fast Breeder Reactors in our country. ***The PFBR is being built with the design and technology developed at the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam.***

India has developed two types of advanced reactors, namely, AHWR and AHWR300-LEU, to adopt a large scale utilisation of thorium for power generation in Stage-3 of the nuclear power program. These reactors are of 300 MW capacity and of boiling light water cooled and heavy water moderated reactor.

AHWR reactor will use Thorium-Plutonium or Thorium-Uranium233 as fuel, while AHWR-LEU reactor will use Thorium-Low enriched Uranium fuel.

Conclusion

India is poised to achieve significant growth in nuclear power generation in the years to come, and nuclear power generation capacity will reach to the tune of 25 GW by 2030. The second and third-stage nuclear power generation strategy will be accelerated to achieve long-term energy security. Nuclear power will play a significant role in realising the net-zero carbon commitment to be achieved in 2050, considering the lower carbon footprint.

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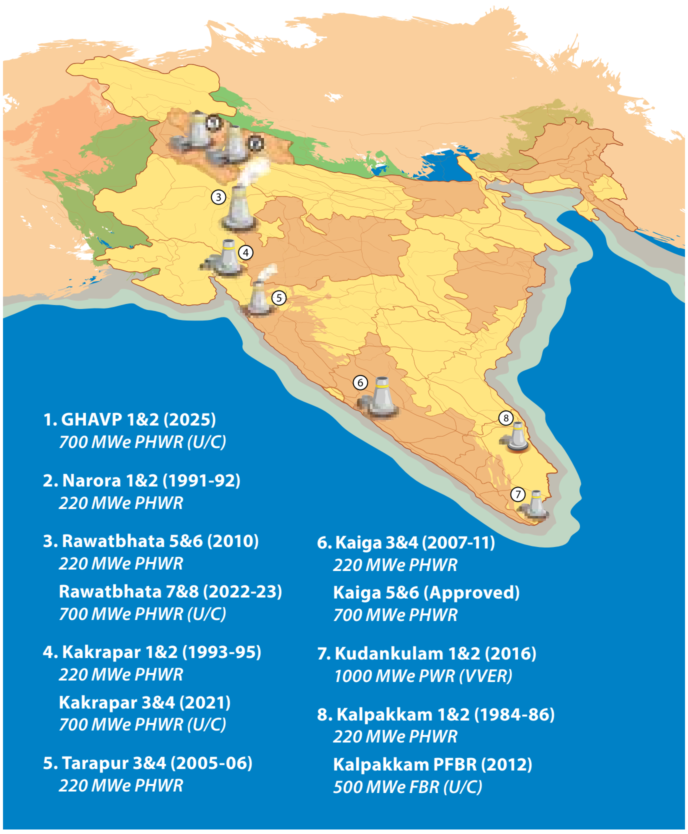

TECHNOLOGY DEVELOPMENT AND AUTOMATION FOR OPERATING NUCLEAR PLANTS

Engineering Assistance to **Periodic Safety Review of Operating Nuclear Plants, Plantlife extension studies,** is a growing business area in India and Globally as more plants are approaching their design life. This involves Deterministic and Probabilistic safety assessment of operating nuclear assets. ***TCE is currently the only Indian consultant assisting in this area for commercial-scale nuclear plants.***

TCE has successfully developed the Deterministic Safety Assessment (as a new service offering) and is engaged with clients including **NPCIL-PHWR, NPCIL-LWR and IGCAR.**

Deterministic safety assessment (as per Conservative Deterministic Failure Margin (CDFM) method) of any structure/component involves the following stages

- Performing Finite Element (FE) Analysis of the structure/component
- Digitising the As-built strength of various structures and components.
- Finding the margin available to assess the as-is condition of the components. (High Confidence of Low Probability of Failure (**HCLPF**) factor)

This involves handling massive volumes of as-built data and FE analysis results.

Anticipating the need for an automation-tool to optimise the process, an integrated **one-click** program, **"SMART", which integrates a suite of modules**, has been developed which extracts and links FE Analysis results (Demand), with as-built digital data of the plant (Capacity) to assess the Seismic Margin available, for various structural elements.

The advantage of having this technology and set of tools developed has helped TCE retain its position as a monopoly supplier in this area and working on repeat orders from DAE.

Since the automation is entirely **modular based on standard work-flows**, it is effortless to extend it for any other international design codes or accommodate any technological advances. ***TCE is currently expanding the tool for Russian SNiP codes for an ongoing Light Water Reactor project.***

The tool's efficiency was a significant challenge as the run-time had to be optimised for enormous data volume involving millions of numerical calculations. TCE mitigated this by adopting careful programming methods, including a modified numerical search method where the computational speed has been improved, apart from automating the process.