Kakrapar Atomic Power Plant-NUCLEAR ENERGY

GS-Paper-3 Nuclear energy (S&T) (PT-MAINS)

Kakrapar Atomic Power Plant is the country’s first 700 MWe (megawatt electric) unit, located in Gujarat. It is the biggest indigenously developed variant of the Pressurized Heavy Water Reactor (PHWR). The operationalization of India’s first 700MWe reactor marks a significant scale-up in technology. It has recently achieved its criticality, which is a landmark event in India’s domestic civilian nuclear programme.

It is significant in terms of optimization of its PHWR design. It addresses the issue of excess thermal margins and an improvement in the economies of scale, without significant changes to the design of the 540 MWe reactor.

'Thermal margin' refers to the extent to which the operating temperature of the reactor is below its maximum operating temperature. The 700MWe capacity would constitute the biggest component of the expansion plan of India to ramp up its existing nuclear power capacity of 6,780 MWe to 22,480 MWe by 2031.

**Criticality means:** The normal operating condition of a reactor, in which nuclear fuel sustains a fission chain reaction. A reactor achieves criticality when each fission event releases a sufficient number of neutrons to sustain an ongoing series of reactions.

**What is Nuclear Energy?**

Nuclear Energy is the energy in the nucleus or core of an atom. Tiny units that make up all matter in the universe are called atoms.

**How is Nuclear Energy produced?**

Nuclear energy is released by splitting the atom, using the process called Nuclear fission.

**How is electricity produced using Nuclear Energy?**

A nuclear reactor is a power plant that can control nuclear fission to produce electricity. In the nuclear reactor, uranium is used as fuel. Atoms of uranium are split, which creates fission products which cause other uranium atoms to split, thus creating a chain reaction. The energy from this chain reaction is released in the form of heat. This heat is used to warm the nuclear reactors cooling agent, which results in the formation of steam. This steam turns the turbines, which drive
the engines or generators to produce electricity.

Where was the first nuclear reactor located, that produced electricity?

Argonne National Laboratory was the first nuclear reactor to produce electricity was located in Idaho, USA. It was in the year 1951.

Where was the first nuclear power plant designed to provide electricity to a community?

It was set up in **Obninsk, Russia in 1954.**

What are the advantages of electricity produced using Nuclear Energy?

- It is a source of clean energy.
- It helps in the development of a country’s economy without adversely contributing to climate change.
- It does not emit any greenhouse gases.
- It can be built in urban or rural areas.
- Nuclear Energy – Electricity production across the Globe
  - Approximately 10% of the world’s electricity is produced using nuclear energy.
  - Worldwide, nuclear power plants are operational in around 30 countries.
  - In France, approximately 75% of the electricity is produced by Nuclear energy.
  - A total of around 450 nuclear reactors are operating worldwide for generating electricity.

Uses

- Provides electricity to a nation without polluting its environment unlike electricity produced from thermal sources like coal.
- Source of huge employment for a nation.
- It helps in boosting the economy of a nation and helps in achieving Sustainable Development Goals.
- Nuclear power is used for space explorations.
- Used for providing potable water through desalination
- Used in cancer treatment
- Used for sterilizing medical equipment.
- A country’s security needs are addressed by using nuclear-powered submarines and nuclear powered
- Nuclear radiation is used in the treatment of food by killing bacteria, insects and parasites that cause illness.
- Nuclear energy could play a major role in transportation by acting as a substitute for fossil fuels.

Nuclear Energy Facts – India
Till 2009, India was excluded from global nuclear trade as it was non-signatory of the Nuclear Non-proliferation treaty due to its nuclear weapons program. This was a hindrance in the development of India’s Civil Nuclear energy program.

Approximately 2.5% of India’s energy requirements are met through nuclear energy.

Locations of Nuclear Power Plants – Planned in India

- Gorakhpur
- Chutka – Madhya Pradesh
- Mahi Banswara – Rajasthan

Locations of Nuclear Power Plants – Proposed

- Haripur – West Bengal
- Rajouli, Nawada – Bihar
- Bhimpur – Madhya Pradesh
- Jaitapur (Ratnagiri District) – Maharashtra
- Kovvada (Srikakulam District) – Andhra Pradesh
- Nizampatnam (Guntur District) – Andhra Pradesh
- Pulivendula (Kadapa District) – Andhra Pradesh
- Chhaya – Mithi (Bhavnagar District) – Gujarat

Locations of Uranium Resources

- Tummalapalle (Kadapa District) – Andhra Pradesh
- Nalgonda District – Telangana
- East Singhbhum District – Jharkhand
- West Khasi Hills District – Meghalaya
- Udaipur District – Rajasthan
- Yadgir District – Karnataka
- Rajnandgaon (District) – Chhattisgarh
- Sonbhadra District – Uttar Pradesh
- Rudraprayag District – Uttarakhand
- Una District – Himachal Pradesh
- Gondia District – Maharashtra

The Indian nuclear programme was conceived based on, unique sequential three-stages and associated technologies essentially to aim at optimum utilization of the indigenous nuclear resource profile of modest Uranium and abundant Thorium resources. This sequential three-stage program is based on a closed fuel cycle, where the spent fuel of one stage is reprocessed to produce fuel for the next stage.

The commercial nuclear power program of the first stage (comprising of PHWRs and imported LWRs) is being implemented by Nuclear Power
Corporation of India Limited (NPCIL), and the second stage (comprising of Fast Breeder Reactors) by Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), both companies owned fully by the union government in accordance with the provisions of the act.

**STAGE 1: Pressurized Heavy Water Reactor using**

- Natural UO$_2$ as fuel matrix.
- Heavy water as moderator and coolant.

**STAGE 2: Fast Breeder Reactor**

- India’s second stage of nuclear power generation envisages the use of Pu-239 obtained from the first stage reactor operation, as the fuel core in fast breeder reactors (FBR).

**STAGE 3: Breeder Reactor**

The third phase of India’s Nuclear Power Generation programme is, breeder reactors using U-233 fuel. India’s vast thorium deposits permit design and operation of U-233 fuelled breeder reactors.

**Research Reactors:**

- **DHRUVA Reactor** at BARC was designed, constructed and commissioned by Indian Engineers and scientists. Natural U is the fuel used and heavy water as moderator and coolant, Dhruva enabled India to attain self sufficiency in the production of radioisotopes.
- **Kamini, a 30 kWt reactor** at the Indira Gandhi Centre for Atomic Research at Kalpakkam, achieved criticality in October 1996 for providing neutron radiography facilities and is a small but significant step towards utilization of our vast thorium reserves. It is the only operating reactor in the world using U-233 fuel.

**Institutions involved in Nuclear energy Development**

India’s Atomic Energy Commission (AEC) was established in August 1948 within the Department of Scientific Research, which was set up in June 1948. The Department of Atomic Energy (DAE) came into existence in August 1954 through a Presidential Order. Thereafter, a Government Resolution in 1958 transferred the DAE within the AEC. The Secretary to the Government of India in the DAE is the ex-officio Chairman of the AEC. The other Members of the AEC are appointed on the recommendation of the Chairman of the AEC.

**DAE’s own Research & Development wings include:**
1) **Bhabha Atomic Research Centre (BARC), Trombay:** A series of 'research' reactors and critical facilities was built here. Reprocessing of used fuel was first undertaken at Trombay in 1964. BARC is also responsible for the transition to thorium-based systems. BARC is responsible for India’s uranium enrichment projects, the pilot Rare Materials Plant (RMP) at Ratnahalli near Mysore.

2) **Indira Gandhi Centre for Atomic Research (IGCAR):** IGCAR at Kalpakkam was set up in 1971. Two civil research reactors here are preparing for stage two of the thorium cycle. BHAVINI is located here and draws upon the centre’s expertise and that of NPCIL in establishing the fast reactor program, including the Fast Reactor Fuel Cycle Facility.

3) **The Raja Ramanna Centre for Advanced Technology (RRCAT):** Multi-purpose research reactor (MPRR) for radioisotope production, testing nuclear fuel and reactor materials, and basic research.

4) **Atomic Minerals Directorate:** The DAE’s Atomic Minerals Directorate for Exploration and Research (AMD) is focused on mineral exploration for uranium and thorium. It was set up in 1949, and is based in Hyderabad, with over 2700 staff.

5) **Variable Energy Cyclotron Centre:** Variable Energy Cyclotron Centre is a premier R & D unit of the Department of Atomic Energy. This Centre is dedicated to carry out frontier research and development in the fields of Accelerator Science & Technology, Nuclear Science (Theoretical and Experimental), Material Science, Computer Science & Technology and in other relevant areas.

6) **Global Centre for Nuclear Energy Partnership:** It will be the DAE’s sixth R & D facility. It is being built near Bahadurgarh in Haryana state and designed to strengthen India’s collaboration internationally. It will house five schools to conduct research into advanced nuclear energy systems, nuclear security, radiological safety, as well as applications for radioisotopes and radiation technologies. Russia is to help set up four of the GCNEP schools.

**Besides carrying out research at its own research centres, the DAE provides full support to seven aided institutions**

1) **Tata Institute of Fundamental Research (TIFR):** The Tata Institute of Fundamental Research is a National Centre of the Government of India, under the umbrella of the Department of Atomic Energy, as well as a deemed University awarding degrees for master's and doctoral programs. TIFR, carry out basic
research in physics, chemistry, biology, mathematics, computer science and science education. Main campus is located in Mumbai, but additional campuses are in Pune, Bangalore and Hyderabad.

2) Tata Memorial Centre: The Tata Memorial Centre commissioned state of the art new operation theatres. For delivering hi-tech patient care, sophisticated facilities such as stereotactic radiosurgery and steriotactic and intensity modulated radiotherapy, were added.

3) Saha Institute of Nuclear Physics: The Saha Institute of Nuclear Physics is an institution of basic research and training in physical and biophysical sciences located in Bidhannagar, Kolkata, India. The institute is named after the famous Indian physicist Meghnad Saha.

4) Institute of Physics: Institute of Physics, Bhubaneswar is an autonomous research institution of the (DAE), Government of India.

5) Institute for Plasma Research: Research and development in fusion technology continued at the Institute for Plasma Research.

6) Harish Chandra Research Institute: The Harish-Chandra Research Institute is an institution dedicated to research in Mathematics and Theoretical Physics, located in Allahabad, Uttar Pradesh in India.

7) Institute of Mathematical Sciences: The Institute of Mathematical Sciences (IMSc), founded in 1962 and based in the verdant surroundings of the CIT campus in Chennai, is a national institution which promotes fundamental research in frontier disciplines of the mathematical and physical sciences.

AERB: The AERB reviews the safety and security of the country’s Operating Nuclear Power Plants, Nuclear Power Projects, Fuel Cycle Facilities, and Other Nuclear/Radiation Facilities and Radiation Facilities. The regulatory authority of AERB is derived from the rules and notifications promulgated under the Atomic Energy Act, 1962 and the Environmental (Protection) Act, 1986. The headquarters is in Mumbai. The mission of the Board is to ensure that the use of Ionising Radiation and Nuclear Power in India does not cause undue risk to health and the Environment. Currently, the Board consists of a full-time Chairman, an ex officio Member, three part-time Members and a Secretary.

NPCIL: Nuclear Power Corporation of India Limited (NPCIL) is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE), Government of India. The Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of thermal
nuclear power plants.

NPCIL is presently (June-2016) operating 21 nuclear power reactors with an installed capacity of 5780 MW. The reactor fleet comprises two Boiling Water Reactors (BWRs) and 18 Pressurised Heavy Water Reactors (PHWRs) including one 100 MW PHWR at Rajasthan which is owned by DAE, Government of India.

The AERB is a regulatory body, which derives administrative and financial support from the Department of Atomic Energy. It reports to the secretary, DAE.

The DAE is also involved in the promotion of nuclear energy, and is also responsible for the functioning of the Nuclear Power Corporation of India Limited, which operates most nuclear power plants in the country.

The DAE is thus responsible both for nuclear safety (through the AERB), as well as the operation of nuclear power plants (through NPCIL). This could be seen as a conflict of interest.