SITING OF INDIAN NUCLEAR PLANTS: THE MODUS OPERANDI

SITAKANTA MISHRA

It is not often that geography contributes something which is relevant to public policy and decision-making.[1] Considerations for siting of nuclear reactors provide one of these rare opportunities because the "locational component" is an important variable that largely determines the consequences of any nuclear emergency. Every industrial activity is prone to extreme meteorological conditions like an earthquake, flooding, tsunami, high velocity winds, etc. depending upon the geological condition it is situated in. Therefore, the engineered safety measures, though important, alone are not sufficient, as safety standards may be quite different in the future. Natural disasters, being location-specific, a geographically realistic and multi-attribute nuclear plant site evaluation methodology is warranted not only to ensure the safety of the current generation but also of future generations. India, which operates 20 reactors in seven locations, with a few more planned, follows a strict code of conduct for siting its nuclear reactors that is mistakenly presumed as being lackadaisical.

Questions have been raised regarding the vulnerability of India's nuclear power plants to natural disasters when the country is on a nuclear expansion mode. Particularly in the aftermath of the Fukushima nuclear disaster, public protest against the proposed Jaitapur nuclear plant was

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1. Stan Openshaw, *Nuclear Power: Siting and Safety* (London: Routlege & Kegan Paul, 1986), p. xi.

The six task forces, constituted for comprehensive safety evaluation of Indian nuclear power plants in the aftermath of the Fukushima disaster, have also indicated "the existence of adequate provisions at Indian nuclear power plants".

intensified. However, it has been overlooked that India has more than 335 reactor years of safe operation[2] and its nuclear plants have survived earthquakes and tsunamis in the past, though of a lesser degree. The six task forces, constituted for comprehensive safety evaluation of Indian nuclear power plants in the aftermath of the Fukushima disaster, have also indicated "the existence of adequate provisions at Indian nuclear power plants".[3] Perceptibly, the concerned public is unaware of India's strategy and principles of nuclear plant siting, design, operation, and de-commissioning. A thorough understanding of these aspects would reveal that no complacency is entertained; rather, each nuclear disaster is monitored keenly for lessons and the desired precautions are undertaken in the Indian nuclear activities. In fact, the Indian nuclear plants are located and designed not only keeping in mind the possible disasters but also the postulated events in relation to design basis and beyond design basis.

POSSIBLE AND POSTULATED NATURAL DISASTERS

Natural phenomena like earthquakes and surface faulting, landslides, rock falling, rock avalanche, debris flows, sand dune migration, wind speed, rainfall intensity, storms, cyclones, flooding, shoreline and riverbank erosion, etc. are a matter of concern for any industrial enterprise, including nuclear plants. However, most of these natural phenomena are location specific, depending upon the geological and meteorological features of the surrounding region. India's seven nuclear plants with 20 nuclear reactors are sited in different geological and meteorological conditions: Kaiga Generation

2. Srikumar Banerjee, "We are for an independent nuclear safety body. We have nothing to hide", interviewed by Raj Chengappa, http://www.tribuneindia.com/2011/20110619/main7.htm, June 19, 2011.
3. NPCIL, "Safety Evaluation of Indian Nuclear Power Plants Post Fukushima Incident (Interim Report), 2011, p. iii.

Station (KGS) in Karnataka; Madras Atomic Power Station (MAPS) in Tamil Nadu; Tarapur Atomic Power Station (TAPS) in Maharashtra; Kakrapar Atomic Power Plant (KAPP) in Gujarat; Narora Atomic Power Station (NAPS) in Uttar Pradesh; and Rawatbhata Atomic Power Station (RAPS) in Rajasthan. Several existing Indian plants are on the coast and many other proposed plants would be sited both offshore and inland.

While one can imagine that an earthquake may affect nuclear plants relative to the distance from the epicentre, theoretically, specific plants are prone to specific natural disasters due to their specific geographic location and climatic conditions. Theoretically, the coastal plants are prone to a tsunami and cyclone, and plants located in the plains may be prone to flooding (due to dam break), tornado, hurricane, etc. In that context, a threat to the plant in Rajasthan can be postulated to emanate from an earthquake and the Gandhi Sagar and Rana Pratap Sagar dam break. The Narora plant in Uttar Pradesh, located in Seismic Zone IV and on the banks of the river Ganges, may be prone to earthquakes and floods. The Madras Atomic Power Station, located in the east coast of Tamil Nadu, witnessed the tsunami in December 2004 and also the coast is prone to cyclonic storms. The Kaiga station, situated near the river Kali in Uttar Kannada district of Karnataka may be subject to the Kadra dam break and flooding. The threat to the Tarapur Atomic Power Station can be postulated to emanate from a tsunami and floods caused by torrential rain as it is located on the west coast. However, a serious look at the siting policy of India would reveal that all "nuclear plants are designed to withstand the loading effects due to hazards from external events."[4] Also, monitoring and upgradation are undertaken constantly to cope with the changing threat situation.

MAP AND MAGNITUDE OF DISASTERS

India is vulnerable to different types of natural disasters originating mainly from its tropical meteorology and Himalayan and littoral geology. The Indian mainland comprises four regions: the Great Mountain Zone, the

4. Roshan A.D, P. Shylamoni Sourav Acharya, "Monograph on Siting of Nuclear Power Plants", Civil & Structural Engineering Division, AERB, http://www.aerb.gov.in/t/sj/Siting.pdf, p. 1.

Among these past natural phenomena, only a few have been causes of concern for India's nuclear establishment.

Plains of the Indus, Ganges and Brahmaputra, the Desert Region, and the Southern Peninsula.[5] However, from the point of view of a threat to nuclear facilities, though specific natural calamities are natural to all these zones, only a few categories of natural disasters draw attention.

Major and minor earthquakes, tsunamis, cyclones, and floods have occurred several times in and around India with some effects. According to the Indian Meteorological Department, over nearly two centuries, from the year 1819 to 2005, around 23 major earthquakes of the magnitude of 6 to 9 on the Richter scale have occurred in India and its neighbourhood.[6] The Atomic Energy Regulatory Board (AERB) records show that at least 10 "major earthquakes" occurred between 1950 and 2006.[7] According to another source, from 1900 to 2004, 133 cyclones and 158 floods of significant intensity have occurred in India.[8] During 1891 to 1986, five storms with wind speeds ranging from 17 m/s to 31.7 m/s were recorded in and around the Gulf of Mannar where the Kudankulam nuclear plant is under construction. One of the storms passed near the Kudankulam Nuclear Power Plant (KKNPP) construction site, while two of the storms, including the strongest one, passed 100 km north of the site.[9] The occurrence of a tsunami in the Indian Ocean and adjacent areas is frequent and sometimes it reaches the Indian shores. Though the occurrence of a tsunami along the Makran Subduction Zone is infrequent,[10] the potential for the generation of destructive tsunamis in

5. "Major Natural Disasters in India", http://www.bmtpc.org/pubs/techno/chapter-1.pdf
6. "List of Some Significant Earthquakes in India and its Neighbourhood", http://imd.gov.in/section/seismo/static/signif.htm
7. Ajai S. Pisharady, A.D. Roshan, Vijay V. Muthekar, "Seismic Safety of Nuclear Power Plants: A Monograph", Civil & Structural Engineering Division, AERB, p. http://aerb.gov.in/t/sj/SeismicSafety.pdf, p. 10.
8. "India Natural Disaster Profile", The Earth Institute, Colombia University, http://www.ldeo.columbia.edu/chrr/research/profiles/pdfs/india_profile.pdf
9. DAE, "Safety Evaluation of Indian NPPs Post Fukushima Incident", Reports of the Task Forces, p. 24
10. George Pararas-Carayannis, "Potential of Tsunami Generation Along the Makran Subduction Zone in the Northern Arabian Sea. Case Study: The Earthquake and Tsunami of November 28, 1945", http://www.drgeorgepc.com/TsunamiPotentialMakranSZ.html

the northern Arabian Sea and its impact on India's western shore cannot be overlooked.

However, among these past natural phenomena, only a few have been causes of concern for India's nuclear establishment. For instance, the floods in 1994, due to the heavy rain in the Tapi district (Gujarat), the Bhuj earthquake in 2001, and the Indian Ocean tsunami in 2004, raised many issues relating to India's nuclear safety preparedness.

The Kakrapar Flooding: In mid-June 1994, Kakrapar experienced unusual heavy rain for 15 hours, together with non-operation of the weir control for the adjoining water pond that caused flooding of the Kakrapar Atomic Power Plant (KAPP) site. Owing to the clogging of the discharge sluice gates of the nearby Moticher lake into the Tapi river, water flooded into the nuclear facility – into the turbine building basement, pump house and cable tunnels from the turbine building and the switchyard.[11] At that time, KAPP-1 was under shutdown state and KAPP-2 was under commissioning.

The 2001 Bhuj Earthquake: The January 26, 2001 earthquake at Bhuj (Gujarat), measuring 6.9 on the Richter scale, was felt at three nuclear plants viz., Kakrapar, Narora and Rawatbhata. All these plants experienced a level of vibration much below (only 5 to 10 percent) the level for which these plants are designed.[12] The inspections of these plants indicated that the distress observed in these plants was "very minor and was too in non-structural elements".[13]

The 2004 Indian Ocean Tsunami: The tsunami in the Indian Ocean that resulted in the earthquake in the Sumatra fault on December 26, 2004, affected MAPS, though without major consequences.[14] During that time, Unit-2 was operating and Unit-1 was under long shutdown for en masse coolant channel replacement and upgradation. The tsunami waves that hit the coast entered the facility and raised the water level in the sea water pump house of the plant, resulting in tripping of the condenser cooling

11. A.R. Sundarajan, K.S. Parthasarathy, S. Sinha, "25 Years of Safety Regulation", AERB, November 2008, p. 37-38.
12. A.S. Warudkar, "Seismic Design Considerations for Nuclear Structures", *Nu-Power*, vol. 15, no. 1 to 4, 2001
13. Ibid., p. 37.
14. "Safety Evaluation Of Indian Nuclear Power Plants Post Fukushima Incident", http://www.npcil.nic.in/pdf/Final_Report_Four_TFs_combined_report.pdf

water pumps.[15] The increase in the water level in the pump house made all the sea water pumps unavailable. Though the damage caused was limited only to some infrastructures like the plant boundary on the sea side and inundation of roads on the east side of the turbine building, it was certainly a wake-up call for the nuclear establishment.

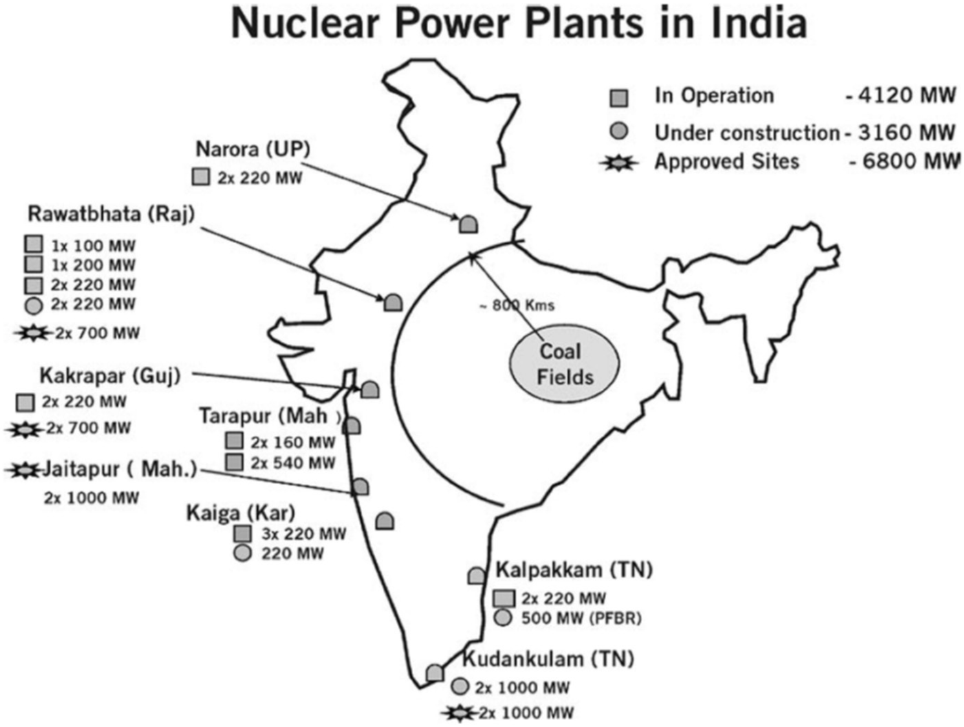
These and other incidents have been taken seriously by India's nuclear establishment. Moreover, a cursory look at the history of natural disasters vis-à-vis nuclear facilities in India would suggest that India's nuclear plants are relatively more prone to earthquake, flood and tsunami occurrences than any other geological and meteorological phenomena that generally affect India's landmass.

THE FEASIBILITY DEBATE

The very issue of the safety of nuclear plants and their effects is centred on the *feasibility of the nuclear power plants'* debate which is as old as India's interest in nuclear energy itself. In fact, the process of setting up nuclear power plants is not a simple and single decision. During the five major stages in the life of nuclear power plants – siting, design, construction, operation and decommissioning – many important criteria are strictly to be met. First of all, there should be a demand for power for which the nuclear option is to be considered. During the first decade after independence, the Government of India decided to establish atomic power projects as it was viewed as a remedy to India's energy ailment in the long-term. Setting up of a Nuclear Power Plant (NPP) in India during those days was considered "viable beyond a distance of 700 km from the coal belt" (Map 1).[16] As the coal deposits in India are concentrated in the eastern regions, the setting up of a coal-fired power plant in western India and in the northwest entails transporting coal over distances exceeding 1,000 km. Therefore, the "economics of nuclear power becomes favourable" in the western, southern and northern areas.[17]

15. Sundarajan, et. al., n. 11, p. 125.
16. M.N. Ray, "Hand Book on Site Selection Process", NPCIL, 2010, p. 1.
17. Yoginder K. Alagh, "Economics of Nuclear Power In India", http://www.igcar.gov.in/nuclear/alagh.htm

Map 1: NPPs Under Operation, Construction and Approved by Government of India



Nuclear Power Plants under operation, construction and approved by Govt of India.

Source: M.N. Ray, Hand Book on Site Selection Process, NPCIL, 2010, p. 20.

On this basis, the first project team was formed under the chairmanship of M.N. Chakravarti in 1959 for selection of sites for NPPs in the western region and it shortlisted two sites – Tarapur and Kakrapar.[18] In 1961, the first Site Selection Committee (SSC) was constituted under the chairmanship of M. Hayath, with the mandate to investigate sites in the southern and northern regions. Out of various sites recommended by this committee, the Government of India accepted two sites – Rawatbhata in Rajasthan and Kalpakkam in Tamil Nadu.[19] Subsequently, the SSC under the chairmanship of M.N. Chakravarti and V.R. Vengurlekar examined the feasibility of

18. Ray, n. 16, p. 1
19. Ibid.

nuclear plants in the northern, western and southern regions (during the mid-1970s). The Narora plant in Uttar Pradesh, which is often criticised for being sited in Seismic Zone IV, was selected by this committee.[20]

With the aim to increase nuclear energy production to 10,000 MWe by the year 2000, an SSC was constituted in 1983 under the chairmanship of M.R. Srinivasan to assess sites in all the four electricity regions – southern, northern, western and eastern. Fifteen sites were selected by this committee for the government's consideration (Table 1).

Table 1: Selected Nuclear Sites at Different Regions

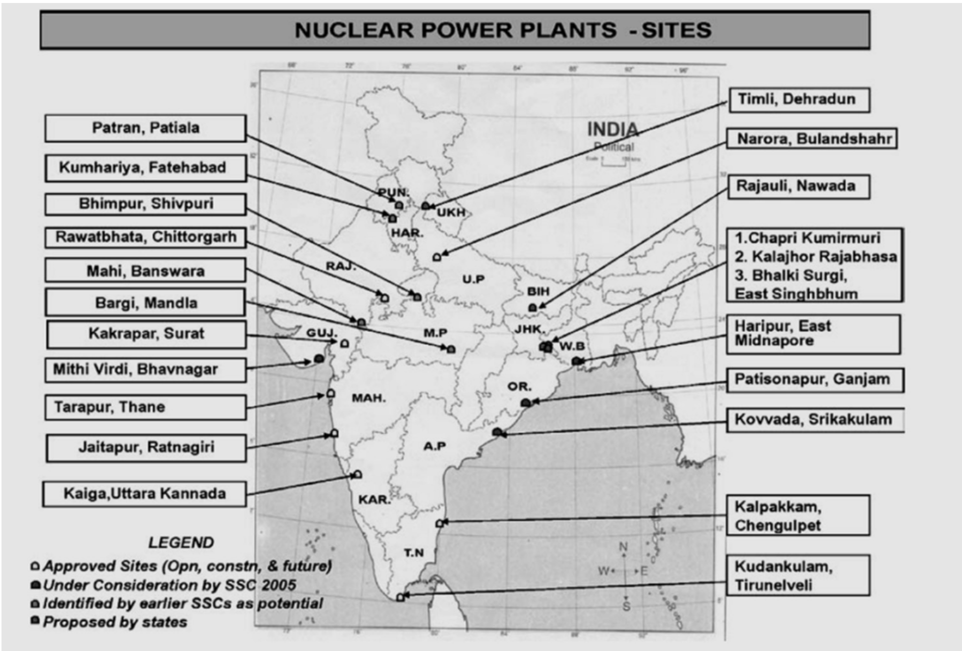
Region	Selected Sites
Southern Region	Kaiga in Karnataka Kudankulam in Tamil Nadu Kalpakkam in Tamil Nadu
Northern Region	Rawatbhata in Rajasthan Narora in Uttar Pradesh (UP) Patran in Punjab Kumharia in Haryana Mahi-Banswara in Rajasthan Matatila in UP
Western Region	Tarapur in Maharashtra Kakrapar in Gujarat Ujaini in Maharashtra Rajapur in Madhya Pradesh (MP) Jaitapur in Maharashtra Bargi in MP

The Technical Committee, under the chairmanship of S. Krishnan identified three more sites for the future – Peringome (Kerala), Nagarjunsagar and Kovvada (Andhra Pradesh). The 1998 SSC, under the chairmanship of Y.S.R. Prasad, studied the additional potential of existing sites. In addition, it identified three new sites – Bargi and Rajapur (Madhya Pradesh) and Mahi-Banswara (Rajasthan) – for consideration. The 2005 SSC focus was

20. Ibid.

on potential coastal sites, but it was also tasked later to consider inland sites, with the concurrence of the state governments. Some of the sites recommended by the SSC 2005 and the Standing Site Selection Committee (SSSC) 2008 (Map 2) have been taken up for serious consideration during the last few years as India has set an ambitious target of 63,000 MWe production by 2032.[21]

Map 2: Existing and Proposed Nuclear Power Plant Sites



Nuclear Power Plants recomended by earlier SSC's,SSC-2005&SSSC-2008 and Sites proposed by States.

Source: M.N. Ray, Hand Book on Site Selection Process, NPCIL, 2010, p. 21

Currently, the feasibility debate of siting of nuclear plants in India seems to be centred more on the government's and the nuclear establishment's initiatives which seem to be driven both by the "economy of nuclear power" and confidence in the safety and security preparedness. On the other hand, the issue of "public acceptance" of sites is based on their safety and security presumptions, environmental protection and displacement of the native

21. "Nuclear Power in India", http://www.world-nuclear.org/info/inf53.html

Among the five major stages – siting, design, construction, operation, and decommissioning – in the lifetime of a nuclear power plant, the siting process involves enormous difficulties as the starting point.

population. The International Atomic Energy Agency (IAEA) Nuclear Technology Review 2009 observed that the Public Acceptance Index (PAI) of nuclear energy in India has grown from around 60 percent in 2005 to around 90 percent during 2008.[22] But, post-Fukushima nuclear disaster in March 2011 and the Nuclear Suppliers Group (NSG) plenary session in June 2011 that voted against the supply of nuclear Enrichment and Reprocessing (ENR) to non-nuclear Non-Proliferation Treaty (NPT) members have raised many apprehensions. However, the findings of six task forces constituted by the Prime Minister in the aftermath of the Japanese nuclear disaster for comprehensive reevaluation of the safety and security of Indian nuclear plants assert that "adequate provisions exist at Indian nuclear power plants to handle station blackout situation".[23]

Therefore, the feasibility debate in India seems to be polarised: (a) a section of the public is opposed to anything nuclear; (b) the government and nuclear establishment are confident about the safety, security and benefit out of their plans and initiatives. In fact, the general masses are unaware of the nitty-gritty of nuclear technology matters and, at the same time, also unaware of the enormous precautions undertaken by the nuclear establishment in all activities, starting from the site selection process and during subsequent activities. The problem seems to be lack of information among the people owing to the communication gap between the scientific community and the public – indicating lopsided nuclear information management in the country.

THE SITING *MODUS OPERANDI*

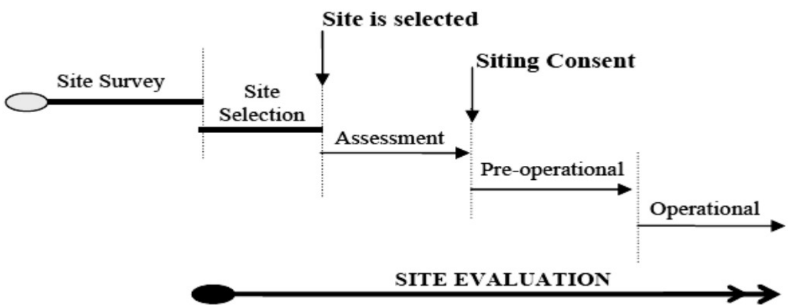
Among the five major stages – siting, design, construction, operation, and decommissioning – in the lifetime of a nuclear power plant, the siting process

22. "Nuclear Technology Review 2009", http://www.iaea.org/About/Policy/GC/GC53/GC53InfDocuments/English/gc53inf-3_en.pdf, p. 15
23. NPCIL, "Safety Evaluation of Indian Nuclear Power Plants Post Fukushima Incident (Interim Report), 2011, p. iii.

involves enormous difficulties as the starting point. The siting process comprises two basic stages – site survey and site evaluation. Both involve enormous consideration on the availability of the required infrastructure, economics, sociological aspects, general safety, technical feasibility and engineerability of the site.[24] Activities, especially during the site survey stage, involve identification of prospective locations, data collection on the candidate site and related preliminary investigation. On the other hand, site evaluation involves satisfactory demonstration of acceptability of the site using the data collected. If the data on a candidate site are satisfactory, derivation of site-related design is undertaken subsequently. However, site evaluation activity (Fig 1) is a continuous process throughout the plant's life to ensure safe operation.

In India, the AERB, as the regulatory agency, stipulates the safety requirements for each stage of nuclear plant activities.

Fig 1: Different Phases of Siting Activities



Source: A.D. Roshan et al, "Siting of Nuclear Power Plants", http://www.aerb.gov.in/t/sj/Siting.pdf, p. 1.

In India, the AERB, as the regulatory agency, stipulates the safety requirements for each stage of nuclear plant activities. The site selection process starts with notification by the Government of India to search for a new site or expansion of the existing one, if possible. The Secretary of

24. A.D. Roshan et al, "Mongraph on Siting of Nuclear Power Plants", http://www.aerb.gov.in/t/sj/Siting.pdf, p. 1.

For selecting or eliminating a candidate site, a large region is investigated, taking into account three basic aspects.

the Department of Atomic Energy (DAE) appoints the SSC which shall function by abiding by all regulations of the AERB and the Ministry of Environment and Forests (MoEF). The SSC is generally composed of members from different departments of the central government having knowledge of the rules and regulations related to the environment and forestry, electric power, health and safety, nuclear engineering, etc. For the ground work, the Chairman of the SSC appoints technical sub-committees whose task is to compile the necessary data on geography, demography, meteorology, infrastructure, and the habitat of the prospective sites by physical surveys. They interact also with the respective nodal officers appointed by the respective state governments regarding all matters. In the process of considering a site, certain stringent criteria are followed, as laid down by the AERB Safety Code (AERB/NF/SG/S-3)[25]:

Acceptance/Rejection Criteria

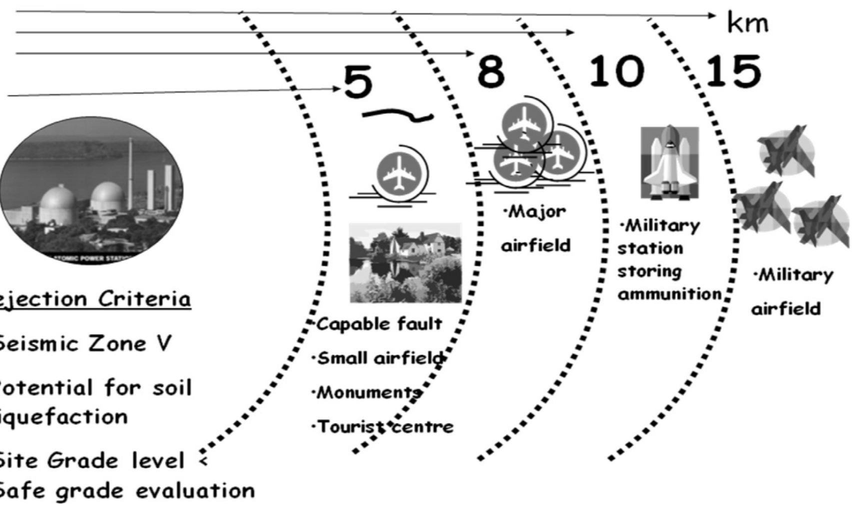
For selecting or eliminating a candidate site, a large region is investigated, taking into account three basic aspects: (1) impact of external events, both natural and human-induced, on the plant; (2) impact of the plant on the site, environment and public; and (3) factors affecting implementation of emergency measures in the public domain.[26] The rejection criteria, generally given in terms of Screening Distance Value (SDV)[27], are applied at the site selection stage to shortlist the candidate sites.[28] Failure to obtain data on them would deem rejection of the candidate site. The mandatory data requirements are on wind, rainfall/flood, vibratory seismic motion, etc. whose effects are necessary to evaluate and adjust during the design process

25. AERB, "Extreme Values of Meteorological Parameters", http://www.aerb.gov.in/T/PUBLICATIONS/CODESGUIDES/sg-s-3.pdf
26. L.R. Bishnoi and Prabir C. Basu, "Siting of Nuclear Installations", http://www.dae.gov.in/ni/nifeb05/PDF/04Siting_nuclear.pdf, p. 7
27. SDV is the maximum distance from the source to the site at which the volcanic phenomenon could be a hazard.
28. Roshan et al., n. 4, p.3.

of the plant. The third category of data is desirable but its non-fulfilment does not affect the plant attributes, e.g. distance to facilities handling inflammable/toxic/explosive substances, population around, etc.[29]

The rejection criteria and SDV are applicable to the candidate site's distance to the seismic fault or the seismic zone it is situated in, proximity to airports, defence installations, distance from industries, and historical monuments.

Fig 2: SDV Rejection Criteria



Regions falling in Seismic Zone V (Map 3), as per Bureau of Indian Standards (BIS) 1893, are strictly rejected for nuclear projects. Environmentally sensitive locations like national parks and marine environment may invoke the rejection criteria. Existence of places like architectural or historical monuments, pilgrimage or tourist interest within 5 km of the site, a major airfield within 8 km, a military station storing ammunition within 10 km and a military airfield within 15 km are rejection criteria for a candidate site.[30] The site is also evaluated keeping in mind the safety aspects of storage and transport of radioactive materials and emergency evacuation.

29. Ibid.
30. Ministry of Environment & Forests, "Environmental Impact Assessment Guidance Manual for Nuclear Power Plants, Nuclear Fuel Reprocessing Plants and Nuclear Waste Management Plants", March 2010, http://moef.nic.in/Manuals/Nuclear%20Power%20Plants_may-10.pdf

In India, seismic guidelines and design requirements for the NPPs are "quite stringent" and generally they are designed for two levels of earthquakes.

Seismic Event Considerations: The Indian National Standard ("Criteria for Earthquake Resistant Design of Structures", *IS 1893*)[31] divides the country into four seismic zones – Zones II, III, IV and V – and specifies the maximum possible earthquake in each zone (Map 3). The Geological Survey of India (GSI) has also compiled a catalogue of Indian earthquakes by studying extensively the seismic events. Accordingly, earthquake resistant design structures are prescribed for both civilian and industrial structures, mainly to transfer the inertial force caused by the earthquake safely to the foundation, without causing damage to the structure.[32]

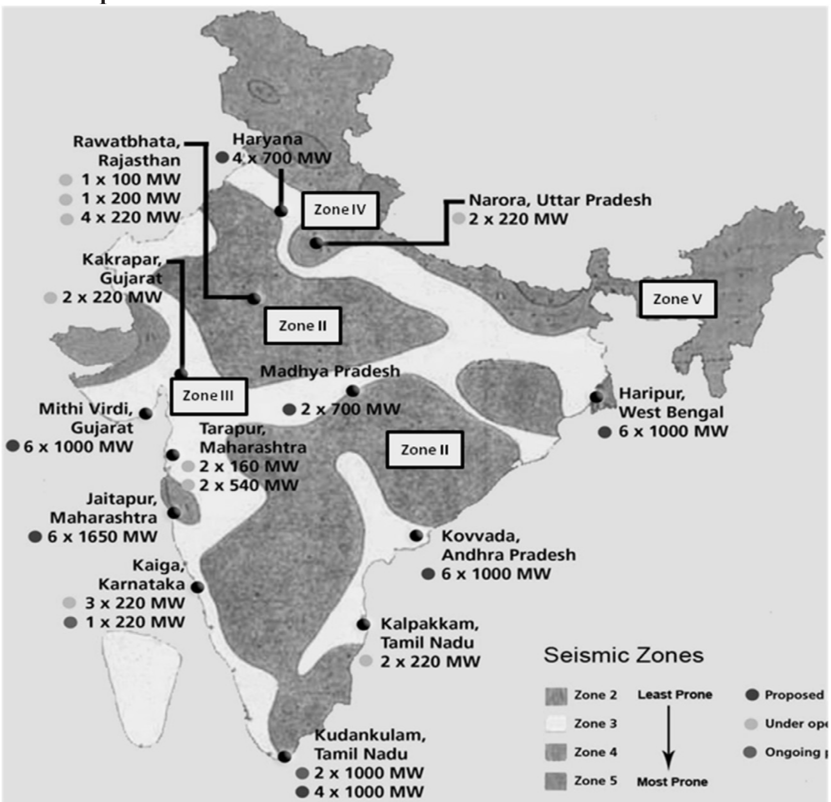
In India, seismic guidelines and design requirements for the NPPs are "quite stringent" and generally they are designed for two levels of earthquakes, namely the S-1 level earthquake or Operating Basis Earthquake (OBE), and the S-2 level earthquake or Safe Shutdown Earthquake (SSE).[33] The OBE level seismic event is the event corresponding to the earthquake level which is expected to occur at least once during the life of the plant. The SSE corresponds to the credible maximum seismic event expected at the site and is determined considering the local geology and seismology and specific characteristics of local sub-surface material.[34]

The straightforward approach to mitigate threats out of any seismic event is not to allow siting of any NPPs in seismic volatile regions. It is ensured that no nuclear plant is sited in Zone V that constitutes the Himalayan belt and northeast India. So far, most of the Indian nuclear facilities are located in Zones II and III which are less prone to seismic hazards. Only the Narora plant is situation in Zone IV; however, many upgraded safety features have

31. "Indian Standards on Earthquake Engineering", http://www.bis.org.in/other/quake.htm; Bureau of Indian Standards, IS 1893, "Criteria for Earthquake Resistant Design of Structures: Part 1, General Provisions and Buildings", 2002.
32. "Learning Earthquake Design and Construction; What are the Seismic Effects on Structures?", http://www.ias.ac.in/resonance/Oct2004/pdf/Oct2004Classroom2.pdf
33 AERB, "Safety Guide for Seismic Studies and Design Basis Ground Motion for Nuclear Power Plant Sites", AERB/SG/S-11, 1990.
34. Ajai S. Pisharady, et al., "Seismic Safety of Nuclear Power Plants: A Monograph", Civil & Structural Engineering Division, AERB, p. 1.

been introduced to the facility.

Map 3: India's Nuclear Plants in Different Seismic Zones



Source: http://www.downtoearth.org.in/dte/userfiles/images/Earth_quake_map.jpg

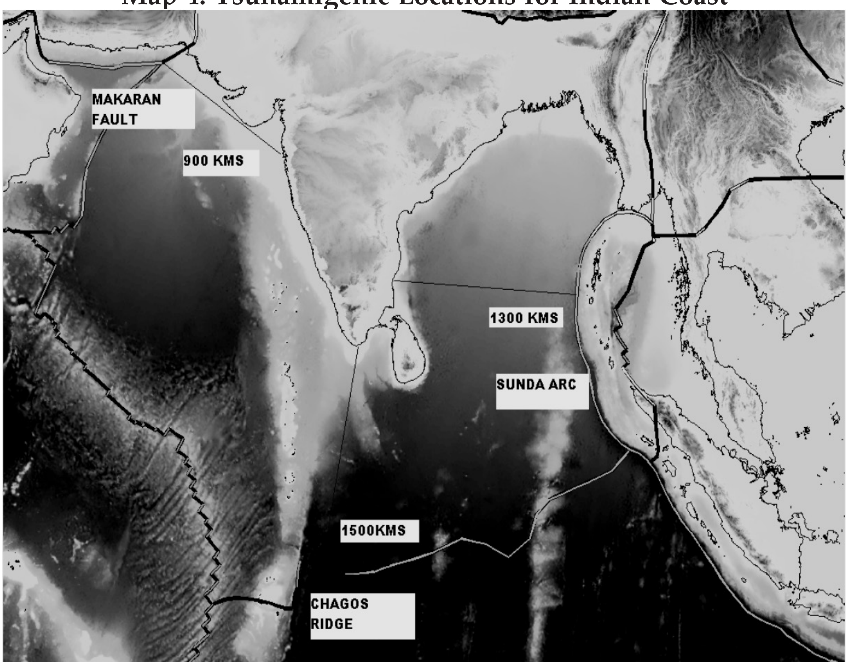
More importantly, a seismic design is adhered to from the very inception of the plant, taking into account the intensity, magnitude and history of earthquakes that have occurred in the region and adjacent to it. On this basis, a site specific seismotectonic report is prepared, using the services of expert geologists and seismologists from the Geological Survey of India (GSI), Atomic Mineral Exploration Directorate (AMDER), National Geophysical Research Institute (NGRI, and National Institute of Rock Mechanics (NIRM).[35] The report covers all the faults and lineaments

35. Ray, n. 16, p. 14.

that exist within a radius of 300 km around the site, in addition to all the seismic events recorded and postulated against these faults/lineaments. The geotechnical investigation report prepared by them has to be based on drilling of at least 6 boreholes each up to a depth of 60-100m.[36]

Tsunamigenic Survey: As a corollary to the seismotectonic survey, the tsunamigenic study takes into account the distance faultlines which might cause a tsunami that reaches Indian shores. There are expressed apprehensions on off-shore nuclear facilities, especially the proposed Jaitapur nuclear plant, that might be affected by a tsunami flood. As Map 4 shows, the nearest faultline in the northwestern direction is the Makran fault, which is 900 km away. The nearest faultline in the south is the Chagos Ridge which is 1,600 km away from Indian shores. In the southeastern side, the Sunda Arc fault is 1,300 km away.

Map 4: Tsunamigenic Locations for Indian Coast



Source: S.A. Bhardwaj (NPCIL), "Indian Nuclear Reactors – Siting and Technology Issues", paper presented at CAPS seminar on Nuclear Energy Post-Fukushima, April 2011, New Delhi.

36. Ibid., p. 9

From the safety and security point of view, the allegation over the proposed Jaitapur plant as unsafe seems misplaced. Jaitapur comes under Seismic Zone III where severe seismic activity is less likely. The nearest faultline is far away from Jaitapur; rather, the special advantage of Jaitapur is that it is adjacent to the sea and is at a height of 20m above sea level which is a natural tsunami saviour.[37] Particularly for the coastal plants, it is ensured that "Site Grade Level", at least "Safe Grade Elevation" (estimated based on highest flood level due to rain, dam break, flooding due to storm surge/tsunami and high tide in the sea) is maintained.[38]

Once the seismogenetic and tsunamigenic report is obtained, the AERB performs detailed multi-tier safety reviews for the projects for all major consenting stages. For siting consent, the SSC performs the first tier review, the Advisory Committee for Project Safety Review performs the second tier review and the Board of AERB performs the third tier review.[39] The extensiveness of the review process can be assessed from the 530 Safety Committee meetings, 325 Working Group meetings, and 28,000 mandays spent for the review process of the TAPS-3&4 site only.[40]

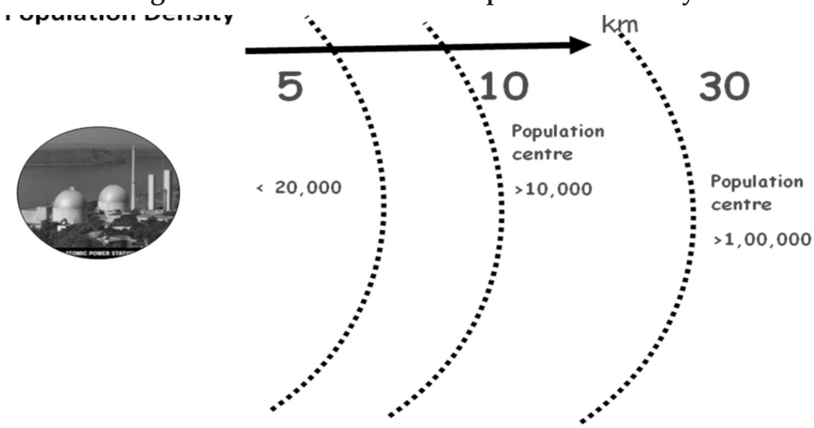
After the preliminary geological and meteorological survey, if the data collected satisfy the defined parameters, a site specific seismic blueprint of the plant is designed with site specific requirements which are also subject to a multi-tier review. For the construction and commissioning stage, the first tier review is carried out by the Design Safety Review Committee; the second tier review is by the Advisory Committee for Project Safety Review; and the Board of AERB performs the third tier review.[41] As per the AERB Safety Guide No. AERB/SG/G-8, the most desirable criterion is the specific density of population in the vicinity. In the candidate site, the population density should be less than 2/3 of the concerned state's average population density. Population within 5 km (sterilised zone) should be less than 20,000

37. "We will open up our n-programme: Srikumar Banerjee", Interview of Sri Kumar Banerjee, Chairman DAE by Iftikhar Gilani, at http://www.tehelka.com/story_main49.asp?filename=Ws300411INTERVIEWII.asp, April 30, 2011.
38. "Hydrologic Engineering", http://pbadupws.nrc.gov/docs/ML1104/ML110410238.pdf
39. AERB, "The Regulatory Process Related to Nuclear Facilities and Its Implementation", http://www.aerb.gov.in/T/documents/regprocess.pdf
40. Ibid.
41. Ibid.

persons. The distance of population centres beyond 10,000 persons should be at least more than 10 km and the distance of large population centres exceeding 1,00,000 persons should be more than 30 km.[42] Also, the location of a port/dry port should be at a distance of 5 km and the terrain of the candidate site should be reasonably flat.[43]

Before starting any further steps, environmental clearance from the MoEF is mandatory.

Fig 3: Desirable Criteria – Population Density



Environmental Impact Assessment

Before starting any further steps, environmental clearance from the MoEF is mandatory.[44] If the candidate site is offshore, clearance under Coastal Regulation Zone (CRZ) Notification (1991) is also mandatory. Through the Environment Impact Assessment (EIA) report and clearance from CRZ, the environmental cost benefit analysis, project risk assessment, disaster management and emergency preparedness measures are assessed. Also, the public, as an important stakeholder, is to be consulted and an extensive

42. AERB Safety Guide No. AERB/SG/G-8, "Criteria For Regulation of Health and Safety of Nuclear Power Plant Personnel, the Public and the Environment", June 2001, http://www.aerb.gov.in/T/PUBLICATIONS/CODESGUIDES/SG-G-08.PDF
43. Ray, n. 16, p. 8.
44. "Environmental Impact Assessment Guidance Manual for Nuclear Power Plants, Nuclear Fuel Reprocessing Plants and Nuclear Waste Management Plants", March 2010, http://moef.nic.in/Manuals/Nuclear%20Power%20Plants_may-10.pdf

epidemiological and health status survey of the population living within 30-km radius around the proposed site has to be conducted.[45] To get Energy Information Administration (EIA) clearance from the MoEF, the agencies concerned have to provide the following basic information:

The effectiveness of the Indian EIA process for nuclear facilities has been criticised on the basis of the status of the nuclear regulatory body.

- Type of nuclear plant/s proposed to be built, with a brief description of each plant.
- How many plants of each type are operating or are being built in the country?
- What are the advantages of each type of plant proposed to be built at the proposed site?
- What alternatives are available for each plant and what determined the choice made?
- How will these plants help the country and the region?
- How good is the experience in terms of safety and environmental quality from similar plants built elsewhere in the country?
- How many similar plants are planned at present at other places in the country?[46]

Under the EIA notification (2006) and its amendment of December 2009, it is mandatory that the EIA clearance is carried out for all nuclear activities, even if they are constructed as add-ons at existing NPP sites. In this case, these are exempted only from public consultation. If all this information provided is satisfactory and meets the determined criteria, the MoEF would clear the proposed site for the utilities to initiate construction.

However, the effectiveness of the Indian EIA process for nuclear facilities has been criticised on the basis of the status of the nuclear regulatory body – viewed as not independent – and "the extent to which public concerns

45. Ibid., pp. 7-9.
46. Ibid., p. 59.

are incorporated into decision-making".[47] M.V. Ramanna highlights three loopholes in the EIA process. First, the reprocessing plants that chemically process radioactive spent fuel discharged from the nuclear reactors are not subject to the EIA process. Second, the EIA for nuclear projects is commissioned by the project authorities themselves, therefore, it may furnish only positive results to highlight the proposals in a favourable light. Third, the EIA is subject to technical errors and the environmental consultants who prepare the document, largely depend upon the nuclear establishment itself. Fourth, the provision for public consultation and hearing is not maintained in both letter and spirit, and the views of the public are allegedly ignored in decision-making. Therefore, it is alleged that the conflict of interest in the EIA process for nuclear facilities is manifold.

However, it has been overlooked that watertight compartmentalisation of different organs of the nuclear establishment and putting one organ as a check against the other would generate unnecessary factionalism and avoidable tensions. There have been many occasions where the MoEF has rejected outright the site proposals for even minor lacks in the documents furnished by the utilities. Criticism is advanced against the organ of the government in charge of the safety and security of nuclear projects; but there would also be criticism if the government were to distance itself from such projects, promoting independent organisations to deal them instead. The problem, in fact, seems to be lack of trust in government organs that are in charge of nuclear activities and this is precisely because of the lack of adequate nuclear information dissemination, not lack of capability to streamline and regulate the activities.

Disaster Resistant Design and Construction

On the basis of a conservative assessment, two levels of seismic parameters – Safe Shutdown Earthquake (SSE) and Operating Basis Earthquake (OBE) – are prescribed for a nuclear plant. Once the parameters are decided, *design*

47. M.V. Ramanna and Divya Badami Rao, "The Environmental Impact Assessment Process for Nuclear Facilities: An Examination of the Indian Experience", *Environment Impact Assessment Review*, 30 (2010), p. 268.

response spectra and *acceleration time history*,[48] which comprise basic input information for seismic design of structures, are derived. In the absence of detailed past history of earthquakes, Zero Period Ground Acceleration (ZPA)[49] is specified as half of the SSE level.[50] For the purpose of evolving the design, all structures, systems and components of a nuclear plant are classified into three seismic categories, according to their safety requirements. These are Categories 1, 2, and 3 structures, corresponding to the seismic design requirements of SSE, OBE and Bureau of Indian Standard's provisions respectively.

As per the guidelines, even if the candidate plant does not fall under any high seismic zone, it has to be designed to withstand a minimum seismic level.

As per the guidelines, even if the candidate plant does not fall under any high seismic zone, it has to be designed to withstand a minimum seismic level. The current practice is to prescribe a minimum value of 0.10g as zero period acceleration for which a nuclear power plant needs to be designed.[51] The modelling of the plant structure is a process of mathematical idealisation which represents the distribution of mass and rigidity of all elements as accurately as possible. Normally, the two types of model – lumped mass stick model and 3D space frame finite element model – depend on the geometry of the structure planned at the candidate site.[52] (This finite element model is

48. "Seismic design is traditionally performed for most common structures by the means of equivalent lateral static loading or modal spectrum analyses. Nevertheless, time history analyses are required to define real seismic response of structure especially for irregular, highly ductile, critical or higher modes induced structures. Seismic codes specify design spectra for the purpose of the design of buildings and recommend scaling of selected ground motions matching spectral acceleration within the period range of interest to use in the time history analyses." Y.M. Fahjan, Z. Ozdemir and H. Keypour, "Procedures for Real Earthquake Time Histories Scaling and Application to Fit Iranian Design Spectra", International Institute of Earthquake and Engineering and Seismology, http://sismik-guclendirme.com/Fahjan%20et%20al-%20SEE5-2007-Procedures%20for%20Real%20Earthquake%20Time%20Histories-Formatted-Final01_makale2.pdf, p. 1.
49. ZPA is the response acceleration value when the structure is very rigid and there is no amplification of ground spectra because of the structure. (i.e. response acceleration when time period of the structure is zero).
50. Ray, n. 16, p. 14.
51. S.S. Warudkar, "Seismic Design Considerations for Nuclear Plant Structures", *Nu-Power*, vol. 15, no. 1 to 4, 2001, p. 39.
52. Ibid.

used on the basis of analysis of the reactor building having lumped masses representing the floor and equipment masses, structural beams, and soil spring elements.[53])

Examination of the seismic capability of some rotating and moving equipment like the primary shutdown mechanism, reactivity mechanism and electrical-instrumentation panels, through an analytical approach, may not be possible. Functional operability of these active devices is demonstrated by "shake-table testing" by mounting them on a shake-table.[54] The motion, identical to the shake-table, and functional performance is monitored during the table motion and if it fails to perform the intended function, the equipment has to be reviewed. Essential equipment, particularly the diesel generators, are kept at a suitable elevation to avoid flooding. Embankments, wave brakes and boundary walls have been designed accordingly to mitigate any influx of water into the plant premises.

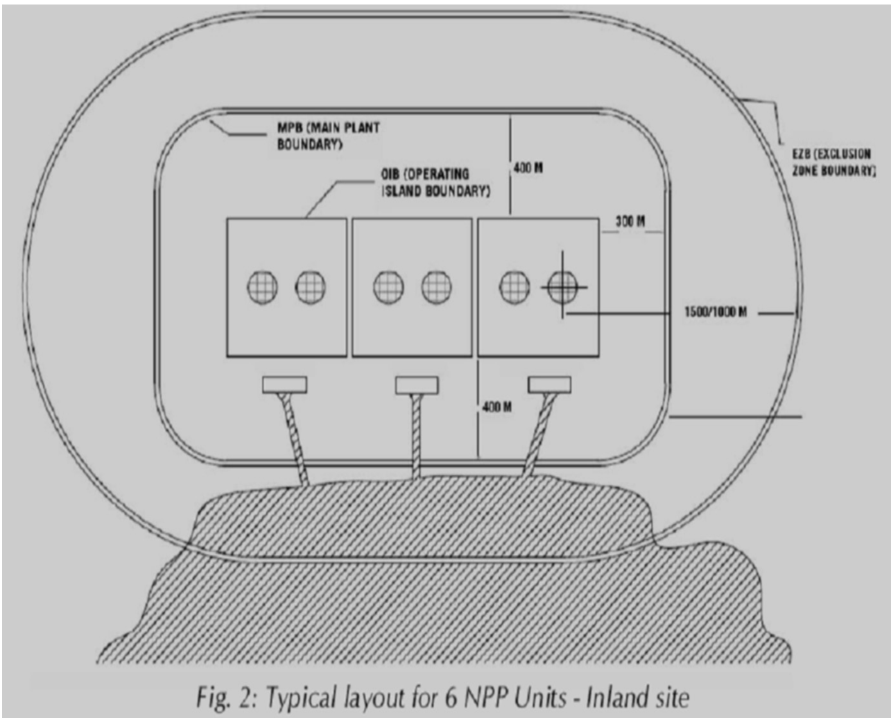
The design of the civil structure of the plant is also analysed by performing a response spectrum analysis as per national international codes. Various international codes like those of the American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE), American Society of Civil Engineers (ASCE), American National Standards Institute (ANSI), etc. are used in the seismic design of the plants. Also, over the years, indigenous expertise has been developed at the Nuclear Power Corporation India Limited (NPCIL), Bhabha Atomic Research Centre (BARC) and several other research institutes and laboratories in the areas of seismic design, analysis and shake-table testing.[55]

Both coastal and inland sites may be prone to location-specific disasters and, therefore, are designed differently (Figs 4 and 5). The AERB Safety Guide (AERB/NPP/SG/S-8) stipulates plant design criteria for an

53. S.A. Bharadwaj, "Broad Steps in Earthquake Resistant Design of a Nuclear Power Plant", *Nu-Power*, vol. 15, no. 1-4, 2001, p. 32.
54. Ibid., p. 35.
55. Ibid., p. 36.

emergency situation and disaster management.[56] The "zoning" concept is followed to ensure emergency preparedness. Generally, three zones are defined for control of the population. The innermost Exclusion Zone (EZ) that surrounds the plant is directly under the control of the plant. The second zone, an annulus around the EZ zone, defines the Sterilised Zone (SZ) where growth of population and habitation is limited and monitored by administrative control. The outermost zone, the Emergency Planning Zone (EPZ), defines the minimum distance to a high population centre. The Indian siting code prescribes an exclusion area of 1.5 km radius around the plant.[57]

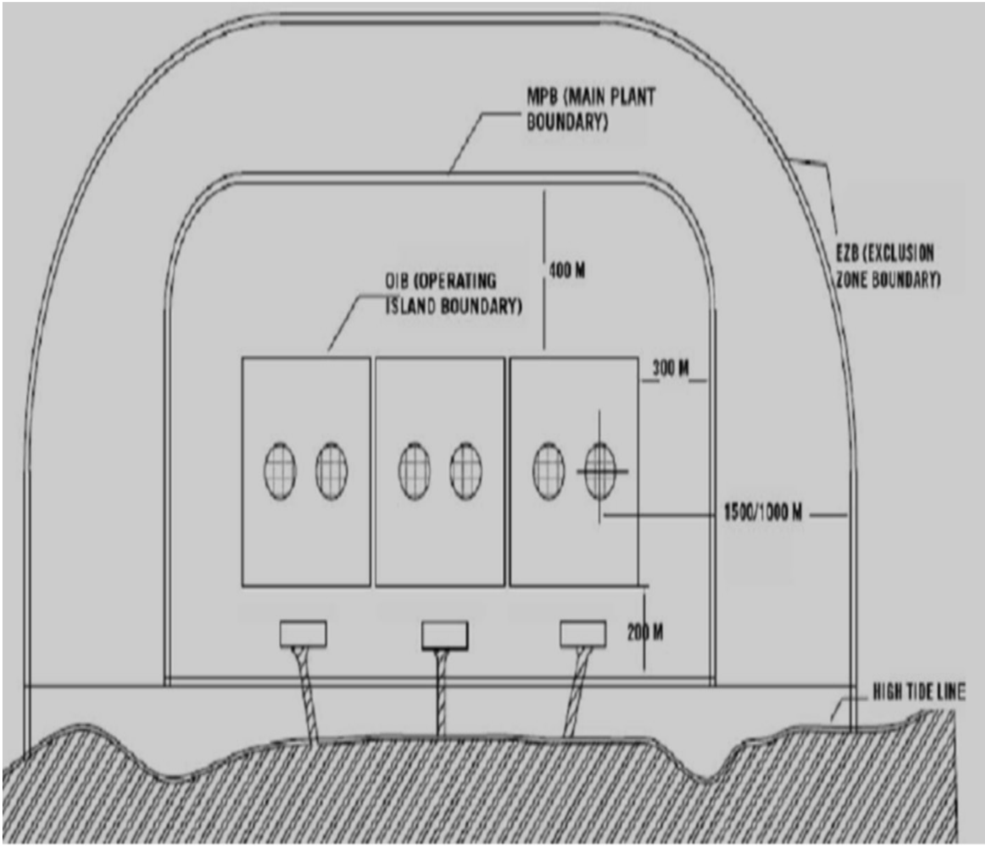
Fig 4: Plant Design for Inland Sites



Source: M.N. Ray, Hand Book on Site Selection Process, NPCIL, 2010, p.19

56. AERB, Site Considerations of Nuclear Power Plants for Off-Site Emergency Preparedness, October 2005, http://www.aerb.gov.in/T/PUBLICATIONS/CODESGUIDES/S-8.PDF
57. Ibid.

Fig 5: Plant Design for Coastal Sites



Source: M.N. Ray, Hand Book on Site Selection Process, NPCIL, 2010, p.18.

Quality Assurance

During the life-time of the nuclear plant, stringent quality of management, construction and maintenance is ensured to eliminate any eventuality. The AERB Safety Guide on *Quality Assurance in Nuclear Power Plants* enumerates specific and comprehensive quality control codes to be adhered to during every activity. The quality assurance programme includes the organisational structure, functional responsibilities, levels of authority and interfaces for those managing, performing, assessing and improving the adequacy of the process.[58] It addresses the management process, including planning, scheduling, resource considerations, environmental and security aspects.

The NPCIL which operates all nuclear plants in the country ensures that the top management is committed to quality, safety and reliability and enforces them in all phases of the plant(s) by creating an appropriate organisational structure and providing resources with the requisite delegation of authority.[59] The quality assurance directorate and heads of the units have the responsibility to ensure effective implementation of the management system requirements at the project sites, operating nuclear plants and supporting organisations. They are authorised for suspension of work in the event of significant deviations in the processes and related activities, when noticed, till they are resolved.[60]

The Civil Liability for Nuclear Damage Act, 2010, fixes the nuclear damage liability with the operator of the nuclear installation (Chapter II, 4(1).[61] This provision, in a way, directs the operator to ensure the quality, safety and security of nuclear materials, installations and operation throughout. In turn, the operator will bilaterally stipulate the liability with the supplier for the components or technology supplied.

On the basis of the sub-committee reports, state government data, seismotectonic assessment report, geotechnical report, and ecosensitivity report, a composite report is prepared on the feasibility of a nuclear power plant at the candidate site. The objective of such a cumbersome process simply is to ensure the safety, security and accountability of each activity undertaken.

THE POST-FUKUSHIMA ASSESSMENT

Partly owing to the global concern over nuclear safety and partly due to the resentment over the proposed Jaitapur nuclear plant, the Indian nuclear

58. AERB, "Quality Assurance in Nuclear Power Plants", http://www.aerb.gov.in/T/PUBLICATIONS/CODESGUIDES/SG-S-10.PDF, January 16, 2009.
59. S.K. Jain, "Statement Of Policy And Authority", http://www.npcil.nic.in/main/Quality_policy.aspx
60. Ibid.
61. *The Civil Liability for Nuclear Damage Act, 2010*, No. 38 of 2010, *The Gazette of India*, Ministry of Law and Justice, New Delhi, available at http://www.dae.gov.in/rules/civilnucliab.pdf, p. 4.

energy debate in the post-Fukushima period seems to reflect three important issues: (1) the findings of the safety audit of nuclear facilities undertaken; (2) the status of the proposed new Nuclear Regulatory Authority; and (3) amicable settlement of the grievances of the Jaitapur public where a nuclear power plant has been planned.

Even though the Indian seismotectonic map is different from that of Japan and simultaneous occurrence of an earthquake and tsunami/flooding is not expected here, a safety audit of all nuclear power stations by the Department of Atomic Energy (DAE) and the Nuclear Power Corporation of India Ltd. (NPCIL) was ordered by Prime Minister Manmohan Singh.[62] Six high-level task forces were constituted with the mandate to investigate the safety status of, and loopholes in, Indian nuclear installations, and to devise an appropriate strategy to address them. The interim Four Task Forces Combined Report says that "adequate provisions exist at Indian nuclear power plants to handle station blackout situation and maintaining continuous cooling of reactor core for decay heat removal".[63]

During the reevaluation, extreme external natural events like an earthquake and tsunami/flood were considered. Generally, the safety features of Indian NPPs are designed for an earthquake with a return period of 10,000 years.[64] According to the first level evaluation (Table 2), the seismic margin of the majority Indian NPPs is close to 0.6g Peak Ground Acceleration (PGA).[65]

62. "Safety Review Ordered in Nuclear Plants: Manmohan", *The Hindu*, March 14, 2011.
63. NPCIL, "Safety Evaluation of Indian Nuclear Power Plants Post Fukushima Incident" (Interim Report), Four Task Forces Combined Report, 2011, p. iii
64. Ibid., p. 7
65. Ibid., p.9.

Table 2: Assessment of Seismic Margin

Station	Seismic Zone	Magnitude (Richter Scale)	Epicentral Distance (km)	Design PGA (g)	Conservative Margin (PGA) (g)
TAPS 1,2	III	5.7	16	0.2g	0.337 to 1.83 @
RAPS-1,2	II	6.0	40	0.1g	0.233 to 2.26 @
MAPS-1,2	II	6.0	20	0.156 g	0.233 to 2.26 @
NAPS-1,2	IV	6.7	12	0.3g	0.6 #
KAPP-1,2	III	6.5	30	0.2g	0.6 #
KGS-1,2,3,4	III	5.7	12	0.2g	0.6 #
RAPS-3,4,5,6	II	6.0	40	0.1g	0.6 #
TAPS-3,4	III	5.7	16	0.2g	0.337 to 1.83 @

@ Seismic requalification based; # Observation/performance based
Source: NPCIL, "Safety Evaluation of Indian Nuclear Power Plants Post Fukushima Incident" (Interim Report), Four Task Forces Combined Report, 2011, p. 9.

In regard to events like tsunami and flooding, originally the TAPS-1&2, RAPS-1&2 and MAPS-1&2 plants were not designed to withstand a tsunami and upstream dam break conditions. However, subsequent upgradation of these reactors is claimed to enhance the safety levels to effectively manage a Station Blackout (SBO) event. The comprehensive safety review of TAPS-1&2 in 2005 examined the station operating performance, safety analysis, ageing assessment and management, structural integrity and plant seismic studies to meet the current safety principles and practices.[66] The latest reevaluation postulated the flood levels and margins due to a tsunami and upstream dam break and advised reassessment of three facilities – TAPS-1&2, RAPS-1&2, and MAPS-1&2 (Table 3).

66. "Task Force Report of TAPS-1&2 (A1)", Safety Evaluation of Indian NPPs Post Fukushima Incident, Reports of the Task Forces, 2011, p. A1: 2.

Table 3: Postulated Flood Levels and Margins

Station	Original designed flood level (in metres)	Revised levels taken for assessment (in metres)	Emergency power DGs elevation (in metres)	Margin available (in metres)
TAPS-1&2	29.33	31.10*	32.30	1.20
RAPS-1&2	354.20	359.60**	356.6 (Original DGs) 366.6 (Retrofitted DG)	 7.00
MAPS-1&2	8.96	10.50*	10.67 (Original DGs) 12.5 (Retrofitted DG)	0.17 2.00
NAPS-1&2	180.80	Design is adequate-revision not required	187.30	6.50
KAPS-1&2	50.30	Design is adequate-revision not required	51.30	1.00
RAPS-3&4	359.60	Design is adequate-revision not required	384.30	24.70
RAPS-5&6	359.60	Design is adequate-revision not required	393.30	33.70
KGS-1&2	38.90	Design is adequate-revision not required	41.30	2.40
KGS-3&4	38.90	Design is adequate-revision not required	41.60	2.70
TAPS-3&4	31.10	Design is adequate-revision not required	32.30	1.20

Source: NPCIL, "Safety Evaluation of Indian Nuclear Power Plants Post Fukushima Incident" (Interim Report), Four Task Forces Combined Report, 2011, p. 10.

To further augment the safety levels, the task forces have advised a series of additional arrangements. They include: automatic reactor shutdown in case of any seismic activity; inerting of the TAPS-1&2 containments; increasing the duration of the passive power sources/battery operated devices; hook-up arrangements through external sources for adding the cooling water inventory to the primary heat transport system; augmentation of the water inventory; training programmes for plant personnel; additional shore protection measures; and additional hook-up points for making up water to spent fuel storage pools wherever necessary for ensuring sufficient inventory.[67]

The task force, while highlighting the adequacy of the existing provisions at TAPS-1&2 to mitigate SBO situations due to external events, has recommended a series of short- and long-term measures taking into

67. NPCIL, n. 63, pp. iii-iv.

account the consequences of postulated events related to an earthquake and tsunami. It recommends self-sufficiency provisions for handling emergencies for seven days without external help; additional training, mock-up drills and disaster management training of personnel need to be hastened.[68] In the long-term, the automatic SCRAM sensing earthquake mechanism needs to be installed. To ensure reliable electric power supply, a tsunami resistant thick wall around the deisel generators and diesel tank need to raised and CNG/gas operated generators should be placed at adequate elevation outside the plant.

The task force on RAPS-2, while recognising the availability of systems and procedures to assure core cooling, has recommended further improvements in five areas: (1) augmentation of water resource; (2) augmentation of feed/make up capability; (3) extension of power sources; (4) improvement in the system; and (5) augmentation of long-term resources.[69] Specifically, the task force has recommended that a dousing tank of 1,800 cu mt capacity and three additional portable diesel pumps to pump water to boilers against 4 kg/cm2 should be made available.[70] The task force on MAPS had suggested strengthening of the existing firewater line, an underground concrete tank of 750 cum., solar powered lighting for buildings, hydrogen management devices, engineering of liquid nitrogen packs and suppression pool water inventory.[71] How stringently and efficiently these recommendations will be implemented is a matter of conjecture. When corruption has engulfed all sectors, the pertinent question is: "Can corrupt India handle nuclear safety"?[72]

THE PROJECT AFFECTED FAMILIES REHABILITATION

The most important aspect of nuclear projects is the 'public acceptance' which depends upon various factors relating to the nuclear plant site and operation. Suitable rehabilitation of the displaced people and the safety

68. n. 66.
69. Ibid., p. A2: 5.
70. Ibid., p. A2: 6.
71. Ibid., p. A3: 8-9.
72. Brahma Chellaney, "Can Corrupt India Handle Nuclear Safety?", http://www.rediff.com/news/column/india-corruption-nuclear-safety/20110318.htm, March 18, 2011.

The politics involved and the vested interests in the opposition to any nuclear activity, raise many confusing issues to instigate the public. As a result, no rehabilitation package works.

of the surrounding population constitute the most pressing among other issues. In India, generally, land acquisition for mega projects has faced public opposition, leading to project delays and cost overruns. Perceptibly, this is owing to mismatch of expectations among the various parties involved: the people, the developers and the regulators. According to M. Shashidhar Reddy, the Vice Chairman of the National Disaster Management Authority (NDMA), rehabilitation of Project Affected Families (PAF) in the country is not being done properly.[73]

With the expedition of new nuclear power projects, public resentment regarding nuclear projects is starting to surface in India. A number of allegations have been raised by the local population. For example, many facilities were shifted 10 km away from the seashore in Kopran village in Tarapur but were not looked after adequately. The Bombay High Court, on the approach of the villagers, has directed the state government to consider giving better fishing facilities and coastal land to the 53 families who have been given alternative accommodation on account of the Tarapur nuclear power project.[74] Even the NDMA has reportedly found loopholes in the relief and rehabilitation package offered to the villagers affected by the Tarapur atomic power station.[75] The opposition to the Jaitapur nuclear power plant project seems to have been triggered on the basis of environmental safety and rehabilitation concerns of the local population. Also, the politics involved and the vested interests in the opposition to any nuclear activity, raise many confusing issues to instigate the public. As a result, no rehabilitation package works. For example, the local residents opposed to the Jaitapur Nuclear Power Plant (JNPP) have refused to accept

73. "Rehab of Project-Affected People not in Right Direction: NDMA", http://news.in.msn.com/national/article.aspx?cp-documentid=5258689
74. Mustafa Plumber, "Look into the Needs of Tarapur PAPs, Bombay High Court Tells Govt", http://dnaindia.com, September 9, 2011.
75. "Loopholes in Tarapur Nuclear Plant Rehab Package, Says NDA", www.dnaindia.com, July 3, 2011.

any compensation, and have not even demanded an increase in compensation. The government has unilaterally offered civic amenities, including the offer to increase the compensation of Rs. 25 lakh per hectare each to the families for 938 hectares of land.[76]

Generally, "science, technology and society constitute a dynamically interactive triad, each steadily growing and influencing the other two in new ways.

The problem, in fact, lies in the lack of understanding of nuclear power's potential, the government's concerns for safety, and the public perception on anything nuclear. Generally, "science, technology and society constitute a dynamically interactive triad, each steadily growing and influencing the other two in new ways. … Society is not just the passive partner arbitrarily unsettled by the progress of science and technology. History is witness as to how active social choices have steered the course of science and technology" and vice-versa.[77] What needs to be done is streamlining and nurturing of a strict technological culture through full public scrutiny to help allay both government and public concerns in all these contentious issues.

CONCLUSION

However, the *modus operandi* for siting of nuclear facilities in India has never been overlooked; rather a concerted effort is always in place to implement these mandates, to ensure safety and emergency preparedness for mitigation of postulated events. Even the peninsular shield of India, which is considered free from severe seismic activity, has been scrupulously examined before siting any nuclear plant there. While all international norms and standards are followed and adopted, an indigenous technology base for all facets of nuclear activity is attempted, taking into account India's

76. Sanjay Jog, "Maharashtra Mulls Annuity Payments for Jaitapur-Affected Families", http://www.business-standard.com/india/news/maharashtra-mulls-annuity-payements-for-jaitapur-affected-families/446597/, August 22, 2011.
77. Vinod K. Gaur, "Why this Seminar?", in Vinod Gaur, ed., *Nuclear Energy and Public Safety* (Indian National Trust for Art and Cultural Heritage, 1996), p. ix.

and the regional geology and meteorology. Both historical and instrumental data are collected and analysed. As the available seismic history of India is short, Micro-Earthquake (MEQ) monitoring[78] is conducted to augment the limited seismological database to ascertain the seismicity of the area and to carry out seismotectonic studies.[79] The seismic monitoring, according to AERB Guidelines (50SG-S11; 1990, Appendix-D), should be started well before (3-5 years) the construction of a nuclear power plant. Once a facility is established, the Environmental Survey Laboratory (ESL) stationed around the facility gathers environmental samples on an hourly basis for analyses.

However, seismic and meterological events have been occurring in India and elsewhere in the world from time immemorial and no location can be described as 'not susceptible' to their occurrence. Also, the fathoming of cosmology by human beings would always be limited as its evolution is much older than the evolution of the human mental faculty. The effort rather is to accumulate data as vast as possible to locate the pattern while getting ready for every postulated event. This is applicable to every industrial undertaking, including nuclear. However, the problem specific to nuclear projects is their popular image and perception which at the moment seem blurred and disproportionate. The public panic based on the idea that 'nuclear activity anywhere is a threat to humanity everywhere' seems to be misplaced, overemphasised, and in the process, the *specificities of nuclear projects* in different parts of the world are overlooked.

78. The MEQ system, a powerful state-of-the-art instrument, consists of a tri-axial sensor (one vertical and two horizontal) and a three-channel digital recorder. The system can provide the approximate direction of the source in addition to the information provided by the one-component station. This system is already commissioned at TAPS and is working satisfactorily. R. Bharadwaj, "Micro-Earthquake Instrumentation at TAPS", *Nu-Power*, vol. 18, no. 1 2004, p. 56.
79. Ibid., pp. 55-56.