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The Indian Civil Nuclear Programme

Issues, Concerns, Opportunities

An interaction with Dr L.V.Krishnan

NUCLEAR SECURITY PROGRAMME

Institute of Peace and Conflict Studies

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The Indian Civil Nuclear Programme: Issues, Concerns, Opportunities

Report By

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The Institute of Peace and Conflict Studies (IPCS), established in August 1996, is an independent think tank devoted to research on peace and security from a South Asian perspective.

Its aim is to develop a comprehensive and alternative framework for peace and security in the region catering to the changing demands of national, regional and global security.

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Dr L V Krishnan started his career in 1958 at the Department of Atomic Energy (DAE), after pursuing a degree in Physics. He worked in the Health Physics division of the Bhabha Atomic Research Centre (BARC), which was then called the Atomic Energy Establishment, Trombay. He specialized in safety analysis of nuclear installations and had the opportunity to set up a nuclear safety research laboratory in Kalpakkam to support the Fast Breeder Reactor (FBR) project which India had just begun developing. He pointed out that safety is a multidisciplinary effort. It encompasses knowledge of reactor physics, design, operation, mining, storage and disposal of spent-fuel, as well as reprocessing. Safety analysis deals with causes for accidents and how they could be prevented or dealt with. It requires familiarity with a wide range of phenomena relating to dispersal of radioactive substances in the environment and effects of radiation on life. Mr Krishnan retired as Director of Safety Research and Health Physics Programmes at the Indira Gandhi Centre for Atomic Research at Kalpakkam in 1997.

The Nuclear Security Programme (NSP) at the Institute of Peace and Conflict Studies (IPCS) conducted an interview with Mr Krishnan in November 2011. The following is a transcript of the interaction.

Tanvi Kulkarni: The Indo-US Nuclear Deal called for the separation of the civil and military nuclear infrastructure of India. Does this include the separation of human infrastructure? Is such a separation possible and what are the difficulties that could be involved?

LV Krishnan: The degree of civil-military separation of nuclear infrastructure is country-specific. Total separation of human infrastructure is very difficult in most countries. The US might have it though as they have several institutions for nuclear sciences and technology that can cater separately for each sector. But in India and other countries with nuclear weapons, the human and institutional resource is smaller. A separate institution like BARC, each for civil and military purposes is neither possible nor feasible in India, primarily because of lack of human resource. In fact, such a separation is not even desirable. Our nuclear technology is evolving slowly and indigenously. The civilian sector is a growing one and requires more human resources. India does not have a large weapons programme. Persons associated with it may spend a small part of their time on it and a much larger part on the civilian aspects. Dr Chidambaram had once mentioned that it is better to work with smaller number of people in large institutions. A group dedicated to strategic work would attract more attention. I am not sure if India has committed to separate its human infrastructure in the civil-military nuclear setup.

Abhijit Iyer-Mitra: The Indo-US nuclear deal in fact does not talk about transfer of people. But if a military reactor producing power is connected to the civilian grid, in case of an emergency, it gets classified as a civilian reactor subject to the clauses of the deal.

Pradeepa Viswanathan: The Kudankulam nuclear power plant project seems to be embroiled in power-politics and vote-bank politics. You have made a strong suggestion that the Government should extend public awareness through the regional and local languages besides Hindi and English. What else could be done besides public awareness?

LVK: Public awareness is to be created and sustained by the experts irrespective of the politics and games of the politicians. For several months, those opposing the construction of the nuclear power plant at Kudankulam reached out to the people through their local language, Tamil, to spread all kinds of allegations and innuendo. They could communicate better with the people and therefore became leaders of the movement. There was little response from the nuclear community and none in Tamil. Similar development can be seen in Jaitapur.

It is important to create public awareness in the local language of the people. Persons having a basic understanding and knowledge of science and particularly students should be addressed and informed about the issue. The professional societies in India have been a disappointment when it comes to awareness creation on environmental issues and raising the calibre of public debates, especially when compared to US and Europe.

Ruhee Neog: Very often nowadays, the Indian government makes statements suggesting that there are attempts to move towards transparency in the Indian nuclear context, but as a subtext, there is also an attempt to move away from it. This is in terms of making information available in the public domain, especially in light of the Jaitapur and Kudankulum agitations. What is the feasibility of putting knowledge of this nature out into the public domain and how can it be regulated so as to make sure that it does not fall into the wrong hands for purposes of sabotage or acts of terrorism?

LVK: Transparency is essential and a certain care needs to be exercised while being transparent for reasons relating to nuclear risk. If everything is made available because the RTI can ask for it citing safety concerns, if this is subsequently published and contains information such as location of the control room, the reactor building lay-out, access points etc; this could also assist people with malicious intent. Some of the information may also be important from the safety analysis point of view. This is why provision of safety-related information in full becomes problematic and the authorities concerned become hesitant.

To some extent, one may have to withhold some of this information but should be as transparent as possible about the rest of it. Ultimately, what is it that people are worried about? They are worried about radiation getting into the public domain, and therefore they have to be briefed about how it can happen and about measures taken to prevent it. They do not have to know how a terrorist can enter and access various points in the reactor complex. I think it is a procedural aspect of how one deals with the transparency question. There is no hard and fast rule here; one is required to play it by the ear. The primary issue that needs to be addressed is: What are the questions relating to safety to be answered and what information can be provided addressing them satisfactorily without affecting plant security.

Alankrita Sinha: How important is the reactor type in terms of the safety of nuclear power plans? After Fukushima there was uproar against Boiling Water Reactors (BWR) as is the case with Tarapur in India. What are your views on this subject?

LVK: Safety is often spoken of in a 'cent per cent' sense, however, nothing is ever a hundred per cent safe. Therefore, the idea is to limit the release of radioactive substances to a certain low level because it is not possible to make it zero. It is to be understood that both, liquid and gaseous discharges, cannot be limited to zero. After all, radioactive substances are present everywhere around us in nature and we are all exposed to radiation to a certain degree. So we study the effects on the health of those people who are exposed to higher levels of radiation in nature as compared to people in other areas. A lot of this kind of study has already been done in India, for example, in Kerala and Tamil Nadu. If at the end of the study it is concluded that these people's health has not been affected by the levels of radiation exposure which is present in their areas, it means that these levels of radiation are perfectly acceptable as they do not pose a threat to people's health.

It is not the reactor type but rather the reactor design which is of importance. The reactor type is defined by aspects like the choice of fuel, the choice of coolant and moderator; but the reactor design integrates them into a safe, commercially viable operating plant. The aim of safety at nuclear power plants is to ensure that people are not exposed to the kind of radiation levels that are dangerous to their health in the worst case scenario. This is where the reactor design has an important role to play. The ultimate aim of the reactor design is to prevent any significant radioactive release.

To ensure that the reactor design takes into account the worst case scenario, it is imperative to work back and ask certain questions. What would happen in a situation where the core melts? How much radiation will be released in such a case? How much of these harmful radiations will find their way into the atmosphere? How can such an event be prevented? The answer to your question is that the reactor type by itself is not enough to ensure safety, but it is the way any type is designed.

In the 1960s, when the first Boiling Water Reactors (BWR) were designed, questions about safety were given as much importance as they are now. These days, especially after the disaster at Fukushima Daiichi 1 and 2, questions have been raised about India's Tarapur BWRs as they are very similar to the ones at Fukushima Daiichi reactors. Concerns about melting of the core and the build up of pressure in the so called dry-well were raised then as they are now. I was a part of the team which discussed the safety of the Tarapur reactors with the American firm that designed them. The team insisted on many changes to the original plan by the designer. We wanted to make sure that hydrogen did not enter the reactor operating floor area, as happened in Fukushima. In Tarapur, there is a large empty chamber attached to the reactor dry-well. If there was to be a pressure-build up in the well, the hydrogen and other gaseous radioactive materials would be led to the large chamber through rupture discs, which do not need electrical power to function.

When the pressure becomes higher than the preset level, the metal in the rupture disc breaks and connects the dry-well to the large chamber with provisions for filling it with nitrogen. This serves two purposes. First, as the hydrogen enters the large chamber, it gets diluted and hence its concentration decreases. The presence of nitrogen means there is little oxygen to favour a violent reaction. Were such a reaction to occur, it is unlikely to impact the reactor operating floor area and the spent fuel pool. These measures as were taken for Tarapur were not to be found in the Fukushima Daiichi reactors.

Another important factor to consider when talking about safety is emergency power supply and its capability to last for several days. Specially introduced safety features as in more recent reactor designs can provide this capability.

In the beginning of a nuclear power program, one tends to be lot more cautious and that is exactly what we were doing in Tarapur. This continues even now as we modify our reactor designs further. At the Tarapur location the focus was more on earthquakes than tsunamis, which are extremely rare there. The Tarapur reactors were designed to withstand certain peak ground acceleration due to an earthquake based on the existing knowledge, but with a safety margin. Later, more recently, when they re-evaluated it, that design basis was found to hold good even now in the light of current knowledge too. This is the kind of safety margin that needs to be provided. This does not appear to have been done in Fukushima units 1 to 4. Take, for example, the Fukushima 5 and 6 reactors, which were built later taking into account higher tsunami levels and had accordingly, chosen the height of location and placement of the diesel generators. This was also the case with three other reactors at the nearby Onagawa site that was closer to the epicentre of the earthquake and tsunami. All these reactors survived while Fukushima Daiichi 1 to 4 did not. There is a saying that 'accidents need not happen. They do happen because you do not take care right at the beginning.' So, the Fukushima accident is mainly the fault of the plant i.e., the company as such and also of the regulator.

It should also be remembered that nuclear reactors are capital intensive. Once you build the nuclear reactors, you recover all your capital and would have paid back all your loans in ten or more years while the plant has a life of 40 or more years. And the fuel cost is very little. There is then a tendency to keep them in operation as long as possible.

But there should be no hesitation to shut down old reactors like the ones in Fukushima if it is found they do not meet current safety requirements.

Note that you cannot realistically compare one country with another in any general terms. Japan had one more problem. It did not have a national grid. Half of Japan operates on alternating current at 50 cycles as we in India do. Tokyo upwards, where Fukushima is, the country operates on 50 cycles. Below that it is all 60 cycles. Now, you cannot easily transfer power from 60 cycles region to 50 cycles region. A large part of the region that was producing power at 60 cycles was unaffected by the earthquake and tsunami that hit Japan in March 2011, and yet they could not transfer power to that part of Japan where Fukushima is. Additionally, in the 50 cycle region where Fukushima is, a number of nuclear power stations were unscathed by the earthquake, but had to be shut down as a precaution. Many coal-fired power stations were damaged by the tsunami so there was very little power available. These are some of the unique problems faced by Japan in the wake of the earthquake and tsunami in March 2011.

A I-M: There is much talk that construction of the EPR in Jaitapur will stop at the stage when the containment dome – designed by the Japanese (Mitsubishi's – Japan Steel Works) is required and this cannot be supplied to India because Japan has not signed a nuclear agreement with us. You had said previously that Indian reactors had double containment in our domes making them inherently safer. Could you shed more light on the EPR's and what role the Japanese play in it?

LVK: As far as I know the EPR was supposed to be a Franco-German collaborative effort with the Germans providing instrumentation and control. The Japanese are perhaps needed for manufacturing the reactor vessel. Only 2 or 3 companies in the world have that ability and this is possibly where the Japanese come in. The containment per se will not be an issue with the EPR.

Questions have been raised by some about the wisdom of India going in for EPR. The British have analysed the safety features of EPR. The problems in Finland have more to do with quality control during construction. The builders are subcontractors engaged by Areva. During quality inspections they found many deficiencies. The Finnish safety authority identified these problems and stopped construction holding Areva as the prime subcontractor responsible.

Areva has however denied responsibility and negotiations are continuing. The Chinese are pressing ahead without any problems in their EPR models. That said I am surprised by the claims that this is an untested design. They say nothing about the 540MW indigenous PHWR reactor which was an upgrade over the 250MW design or the indigenous 500 MW PFBR based on the 15 MW FBTR. The EPR is a 15 per cent upgrade over previous models with the addition of several safety features. So to claim that additional safety features constitute a danger is incredulous.

A I-M: What is the safety benefit of the new subcritical Accelerator Driven System (ADS) reactors? Public literature suggests that they are proliferation proof and much safer than current generation and requires less safety expenditure; also since the technology being so close to operationalisation, they should be adopted immediately.

LVK: To sustain a chain reaction you need a continuous supply of neutrons. In a fission reactor – the fission provides more than 2 neutrons on average. One is absorbed with no gain but one other is harnessed to sustain the reaction by causing another fission. In an ADS the accelerator produces a high energy proton beam which is directed towards a tungsten or lead target inside the core. When this beam collides with the target nucleus it releases about 30 neutrons in what is called a spallation reaction. So you can have a sub-critical reactor turning into a critical system with a sustained fission chain reaction due to the continued supply of spallation neutrons. The advantage is that this chain reaction can be stopped at anytime by turning off the proton beam. With this type then there is no question of a power excursion. This is very different from a conventional fission reactor in which the system by itself is self sustaining and reliably operating control rods are needed to stop chain reaction and maintain a subcritical state. This is a major safety advantage of the ADS.

ADS also helps utilise thorium. Thorium has to be first converted to U233 which requires a steady supply of neutrons. The present plan is to achieve this conversion in the Fast Breeder Reactor of India's 3 stage programme. In an ADS, with a large mass of thorium in the core, the accelerator provides a steady stream of neutrons to convert thorium to U233 which can then be burnt *in-situ*. This is a definite advantage as it makes reprocessing of spent fuel to recover fissile material unnecessary.

The problem really is in building an accelerator that produces protons of energy as high as 1 billion electron volts and a current of over a hundred milliamperes. Many experiments are being carried out with protons of lower energy to understand the phenomena involved. The accelerator has to operate continuously and reliably; the target may have to be periodically replaced. There are many technological problems. Many groups are working on it, India included, with the hope of replacing FBRs but I think this is very far away – not as far as fusion reactors though.

TK: How do you assess India's progress in the three-stage civilian nuclear programme? How pressing is the need to move to the thorium level? Can any stage be advanced or missed to arrive at the third level?

LVK: There is a historical background to Bhabha's vision on the thorium stage of the nuclear cycle. In 1958, at the time of the Second Geneva Conference, an experimental reactor, known as Molten Salt Reactor, was being proposed at the Oak Ridge National Laboratory in the US (the reactor was eventually built but shut down in 1969 after four years of operation). This reactor used a liquid fuel with a mixture of fluorides of Uranium (U) and Thorium (Th). When the fluid passes through the core, some of the thorium gets converted into uranium 233 (U233). The liquid fuel could also be used as a coolant. After extraction of heat from it before it is sent back to the reactor core, some of the U233 could be recovered in a continuous process. In a solid fuelled reactor, we have to wait for a few months to take the fuel out and chemically reprocess it to recover the U233. This process is much faster in a liquid fuelled reactor. Bhabha believed that if the liquid-fuelled molten salt breeder reactor were to succeed, then one could go quickly to the thorium stage with plutonium from Pressurised Heavy Water Reactors (PHWRs) as access to U233 from thorium becomes quicker. But, the prospect of liquid-fuelled reactors failed because of material problems. A new alloy known as Hastelloy was developed but hot spots developed in the material causing it to fail. The advantage of a liquid-fuelled reactor is that the U233 is continuously recovered. If this is not done, another isotope of uranium, U232, builds up; this is a strong source of radiation. Remote handling techniques are required to handle the separated U233 containing U232.

In the absence of molten salt reactors, plutonium from Pressurised Heavy Water Reactors (PHWRs) needs to be used in Fast Breeder Reactors (FBRs) in the second stage to breed enough plutonium for the third stage of fast reactors to utilise thorium.

Now, the Generation IV reactor designs and concepts have retained the molten salt reactor as its compact core is suitable for the thorium fuel cycle. But this technology may not materialise in the near future; and with no immediate access to thorium from these reactors in the near future, thorium will have to be bred in the FBRs, which takes time. Therefore, the thorium stage is unlikely to be realised in the immediate future.

In the meanwhile, it is possible to utilize thorium in thermal reactors to a limited extent using whatever plutonium (or enriched uranium) is available. The Advanced Heavy Water Reactor (AHWR) is designed with this objective. It uses a mixture of thorium with either plutonium or enriched uranium to generate 300 MW. If the U233 could be left to burn inside the reactor *in situ* more power can be generated with the same amount of plutonium or enriched uranium and thorium doesn't need to be reprocessed. The AHWR has enhanced safety features; it does not have a primary pump and involves cooling by natural circulation through hot water displacing cold water. So it is not so much dependent on availability of electricity. Also, steam is produced directly in the reactor which eliminates the need for an external steam generator. This is economically attractive.

But, we can use plutonium more effectively in FBRs rather than in AHWR. FBRs can run indefinitely with the initial supply of plutonium by recycling what is produced during operation. If they are designed better, it would be possible to produce even more plutonium to build another reactor. In the AHWR, with the plutonium-thorium mixture, additional plutonium has to be supplied every year, besides the initial input. However today, we may have access to LeU as a result of the Indo-US nuclear deal. This has led to redesigning of the AHWRs so that LeU can be used with thorium. If this is done, we may be able to initiate now the thorium stage as envisioned. While it may be possible to begin using thorium in this manner, the second stage of plutonium fuelled FBRs of larger capacity viz 500 MW – 1000 MW, would still be needed.

Mallika Joseph: Safety pertains mainly to the internal perimeter of a nuclear facility and security pertains to both, the internal and external perimeter. The possibility of sabotage is an important security threat that can lead to a safety-crisis. Are any of India's nuclear reactors vulnerable to sabotage? What safety mechanisms are called for?

LVK: Indian nuclear reactors have an exclusion zone of 1.5 kms radius which is much larger those in many other countries. The reactor footprint is small and it is surrounded by a large area with many gates to pass through to gain entry to it. But reactors built on the coast are vulnerable to threats from the sea-side. In India, this has received serious attention after the Mumbai attack. The effectiveness of measures taken is not easily confirmed. Coastal patrols and coastal police stations of the state police have been established, but reportedly face many shortcomings including fitness and training issues. Coastal security can be enhanced only up to a certain level. Fishermen cannot be prevented from fishing in nearby areas; their IDs can be manipulated and effectiveness of checking mechanisms cannot be confirmed. We do need to pay attention to security threats to plants from the seaside.

In a reactor complex, the safety-sensitive areas are difficult to reach. It may be easier to get to equipment outside such as the diesel generator but not in to the reactor building. Damage to the diesel generator will not cause a major accident. Diesel generators are required when there is no power available from external sources. In case of damage to the generator, reactor can be shut down and power can be drawn from external sources. Outside power is drawn from three different locations. An attempt at serious sabotage is unlikely to succeed unless all of the external power supply routes are incapacitated. Having said this, security forces have to be prepared for all circumstances. But saboteurs will have utmost difficulty to achieve a crisis-situation of Fukushima standards. The reactor containment design is such as to minimise the release.

As for attack with missiles, it depends on the type and the payload. Plant security takes into account attack from the air too. The reactors have double containment and are designed to withstand an aircrash. There could be fire outside the containment due to the fuel in the aircraft, but that is not expected to cause serious damage the inner containment.

RN: In the area of threat assessment, is there any discussion in India on the possible pre-emption, prevention or containment or spread of: 1) Tacit knowledge or the 'intangibles' is there a consensus on the itemization and definition of it? 2) Malicious actors intending to cause mass panic and hysteria, who do not necessarily have the nuclear capability to do so?

LVK: Tacit knowledge is what one acquires by working with things, not what one gets from books or literature, and this is not so easily transferred unless it is transferred from person to person. Also, even for this transfer, the receiver must observe the work being done, simply describing it is not going to suffice. If he/she has never worked with or seen such a component it is not going to be very effective. There are limitations therefore to tacit knowledge being spread.

Not much is required to induce mass hysteria and panic. If some minor equipment outside the reactor has been damaged and if the station or the plant does not come out immediately and say what it is, and the media gets to report it first, the way they report it can create panic without any evidence of any damage to the reactor. This is where transparency or dissemination of information becomes very important. If there is some bad news the plant must be the first to put it out. If this is not done, exaggerated accounts by word of mouth are spread. The English media might perhaps be a little restrained but the regional media might go overboard.

AS: Pakistan keeps reiterating that their Personnel Reliability Programme (PRP) is iron-clad where nuclear security is concerned. Does India also have a PRP in place?

LVK: The security of the facilities of Pakistan Atomic Energy Commission is looked after by the Army. Some believe that PAEC is not quite a civilian organization. The PRP for the nuclear facilities in Pakistan now, seems to be an insistence by the Americans after the discovery of AQ Khan proliferation network and the alleged claims by Jihadi groups of interest in nuclear weapons. Pakistan claims it has always had a PRP system in place. The Americans claim that they have helped Pakistan's set up this program.

I would say a form of PRP is already a part of government service in India to some extent. When you enter the government service, there is a verification done and you are made to sign certain documents. There is some semblance of a PRP here. As people go higher up in the ranks, as they gain more knowledge of nuclear issues, there is indeed further vetting done. Perhaps, this is not well-known outside. Periodically you have to provide information about yourself to the Administration. Now, how they verify it, is something about which we do not know. However, there is at least some evidence that this is being done. Let me qualify this by saying that I retired about twelve years ago and hence do not know about the changes that have been implemented since then.

As to the question of whether we in India require it, we require it not only from the nuclear weapon proliferation point of view, but also from the standpoint of insider-outsider connivance relating to security of nuclear facilities. PRP is something which is necessary and wise to have.

RN: What is your opinion of media coverage of nuclear activities in India?

LVK: In my observation, in a number of cases, very minor incidents have been highly exaggerated through inappropriate choice of words. For instance, many say that in Fukushima a large number of children have been 'affected' by radioactive iodine. Note the word 'affected'. There is a difference between being affected and showing signs of presence of radioactive iodine in the thyroid. The effect depends on the latter. The measurements at Fukushima indicate that the levels of radioactive iodine in the thyroid of children were far below any level that could cause alarm. What does the use of the word 'affected' do in the public mind except create unnecessary alarm?

Invariably, media reports say that the level of radiation in the environment due to a nuclear incident has increased many times over. This too can sound quite alarming. That increase might still be two or three times less than the radiation levels in some places in nature where people have been living for generations with no perceptible consequences. There must be a lot more care in the choice of words. I would not really blame the media persons because they do not understand the exact nature of how radiation acts. The media as well as the public and the medical professionals too must be better informed.