NON-PERFORMANCE OF GEN-III REACTOR AT KUDANKULAM:

SAFETY IMPLICATIONS FOR AES-2006 VVER REACTORS WORLDWIDE

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Synopsis

Finland's parliament has recently approved a joint venture with Russia to build a VVER 1200 MWe, design AES-2006 pressurized water reactor which 'complies with the IAEA and EUR requirements' of a generation-III (Gen-III). AES-2006 design has not undergone the Gen-III assessment process. Its parent -design AES-92 which was certified as Gen-III in 2007 is missing from the genealogy of AES-2006 given in a presentation by the vendor, Rosatom. We propose that there are strong reasons to believe that this disappearance is due to the dismal performance of the AES-92 reactors at Kudankulam (KK) in India and the controversy surrounding its Gen-III certification. KK Reactor took about 12 years for construction and failed in the commissioning tests seven times. AES-92 received Gen-III certification in 2007 on the basis of fictitious and fabricated data. Rosatom's practice of selling an un-assessed design as Gen-III compliant has implications for nuclear safety globally as this design is being considered in many countries like Belarus, Bulgaria, Finland, South Africa, Bangladesh and Vietnam. In this article, we will chart out the genealogy of the AES-20056 reactor, the history of EUR (European Utility Requirement) certification process of AES-92, performance of the real AES-92 reactor at Kudankulam Nuclear Power Plant (KKNPP) in India and the attributes of its predecessor AES-91 reactor under operation in China since 2007. We will demonstrate that the reason for the deletion of the AES-92 reactor design from the AES-2006 genealogy is the real-world under-performance of the only AES-92 reactor at KKNPP.

1. Introduction

The Finnish Parliament has recently approved a joint venture by the Finnish consortium, Fennovoima and the Russian energy firm, Rosatom for construction of a reactor (design AES-2006), at the Pyhäjoki site in northern Finland. AES-2006 (also designated as VVER-1200), with a thermal output of 3300 MW and net electric output of ~ 1200 MW. According to Fennovoima, this is a "third generation evolutionary pressurized water reactor based on Russian VVER plants"[1.]

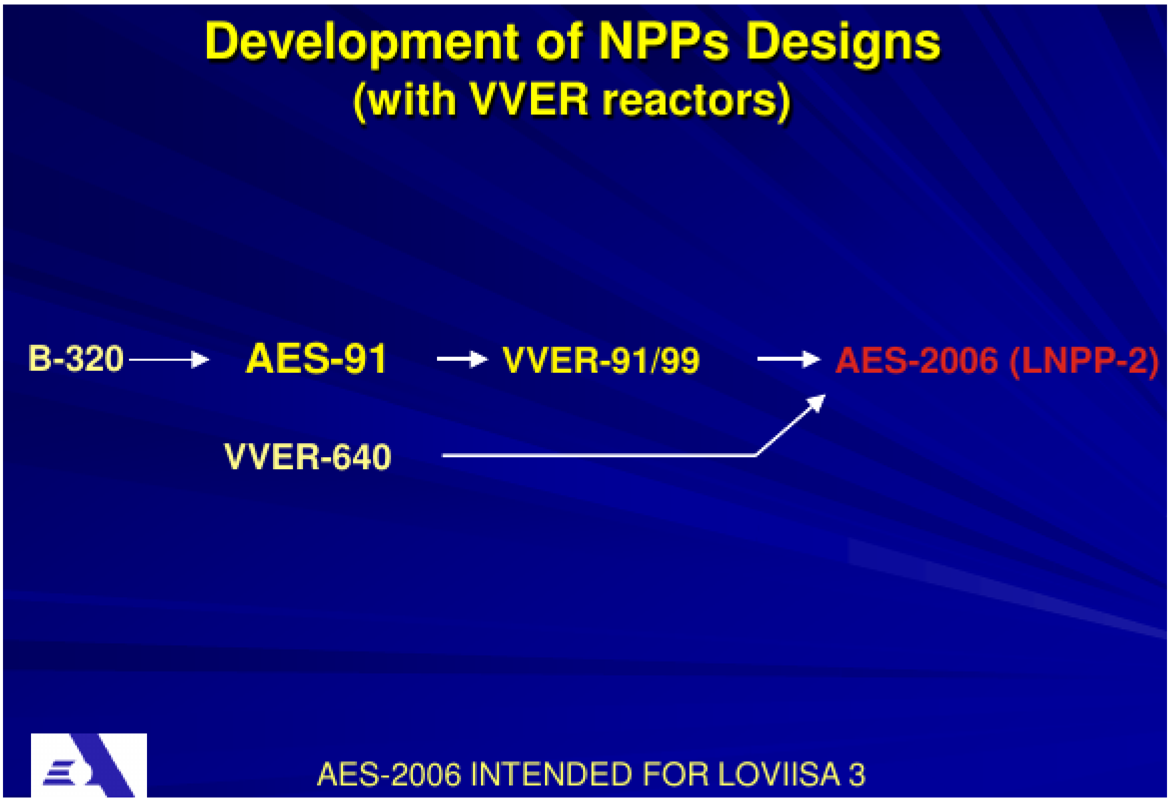
The nuclear reactors commissioned before 1975 belong to Generation -I, those built during 1975-1995 are Gen-II and the latest designs are Gen-III. Gen-III reactors are inherently safer than Gen-II. The certification is done by the Electric Power Research Institute (EPRI) in USA and the European Utility Requirement (EUR) Club, a consortium of utility owners in Western Europe. For a design to be Gen-III compiant, either that design or an earlier design in its 'family tree' should carry a Gen-III certification by EUR or EPRI.

2. Evolution of AES-2006

AES-2006 evolved from V-320, the standard design of 1000 MW pressurized water reactor (VVER). There are three designs in between, -AES91, AES92 and VVER 91/99. Two reactors of designs AES-91 and AES-92 have been constructed in China and India respectively. "The AES-92 incorporated what one Finnish nuclear expert called 'radically simplified' plant systems that included active safety systems, a reduced-power reactor core, and a double containment structure surrounding the nuclear reactor."[2] According to the designer Atomproect, the references for the AES-2006 design are "NPP with VVER-1000/428 and NPP-91/99 for the tender in Finland, updated based on the experience of operating power units VVER-1000/320 and on the design solutions of NPPs with VVER-640 and *AES-92*."[3] AES-2006 reactors are under construction in Leningrad, Novovoronezh and Kalinin in Russia. Deals for AES-2006 are being negotiated with Finland, Belarus, Bulgaria, Bangladesh, Vietnam and India. Coorect genealogy of AES-2006 is given below:

V-230 ---->AES-91 -----> AES-92 -----> VVER 91/99 ------> AES-1006

Rosatom Slide with Missing AES-92 design



3. AES-2006 Design for Finland and Belarus

Finland. The following slide depicting the family tree of ASE-2006, is from a power point presentation about the Finland plant published by the vendor Atomstroyexpert (ASE). The slide which repeats three times has probably escaped the attention of the Finnish decision makers. Four earlier designs of AES-2006 are listed.[4] Missing in the list of earlier designs of AES-2006 is AES-92 design, of which two reactors – one grid connecrted in Oct 2013 and the other nearing completion – exist in India. The presentation also provides far-fetched claims on the performance of AES-91 reactors which has been operational in China since 2007.

Belarus. According to the 'Expert Statement on the Preliminary EIA Report for the proposed AES-2006 reactor in Belarus, published by the Government of Austria, "it is important to note that the NPP-2006 was developed from *NPP-92, which is certified by European Utility Requirements (EUR). Thus, it is plausible that NPP-2006 also fulfills the EUR"*.[5]

4. Gen-III Certification of AES-92 by EUR

In 2005, Rosatom submitted its application for EUR certification of AES-92, showing the two reactors at Kudankulam Nuclear Power Plant (KKNPP) in India, which have been under construction since March 2002, as the prototype. The first description of the AES-92 reactor was provided by SK Agarwal et al, of the Nuclear Power Corporation of India Ltd (NPCIL), in an article published in 2006 in an international journal, *Nuclear Engineering Design*. This paper which revealed that the KKNPP's reactor pressure vessel (RPV) "has *no weld joints in the core region"* and the reactor's core damage fequency is one in 10 million reactor years"[6] was also part of the documentation submitted to EUR. In the concluding EUR seminar in Milan in May 2007, AES-92 was certified as complying with the EUR requirements for Gen-III reactor.[7]

4.1 Equipment Defects in the AES-92 Reactors at Kudankulam, India

The reactor pressure vessel (RPV), known as the heart of a reactor, determines both the safety and the life time of a reactor. RPVs of Gen-II reactors had welds on the beltline (around the middle portion), which increases the risk of RPV failure due to embrittlement and release of radioactivity to the environment. According to the West European Nuclear Regulators' Association (WENRA) one of the main safety issues of VVER-1000 reactor is that "the embrittlement of RPV needs continuous attention, and action will need to be taken if it approaches a hazardous level"[8]

The RPV of the first reactor arrived at Kudankulam in India in January 2005. NPCIL requested Rosatom to speed up the delivery of the RPV for the second reactor which was received in India in June 2005. The RPV was installed inside the first reactor in April 2007, two years after its arrival. A year after the erection, in 2008, the Atomic Energy Regulatory Board (AERB) revealed that "the KKNPP RPV has welds in the core region"[9] and in 2011, the NPCIL announced that the reactor's "core damage frequency is 10^{-5} /reactor-year and its life time, 30 Yrs (40 yrs for RPV)."[10] In other words, the real reactor was 100 times more unsafe than the virtual one certified as Gen-III by EUR.

NPCIL's quality assurance (QA) team, camping in St Petersburg since 2002 should have seen the welds of the RPV, well before Agarwal *et al* wrote the first draft. RPVs had arrived at the site well before the final revision of the manuscript (26th September, 2005). The first author was in the Indian team that negotiated the deal with Rosatom and was also As the Station Director, the first author had access to all inspection reports by the QA team based in Russia and at the site. In spite of this, the authors relied solely on the vendor's advertizement and did not refer to the inspection reports ore describing the equipment. India did not complain to the vendor or inform the EUR Club about the equipment defects. An earlier paper on the counterfeit equipment at KKNPP[11] list several other discrepancies which warrant serious attention by experts as well as the broader civil society.

4.2 Real-world Performance of AES-92 and AES-91 Reactors

AES-92. The reactor at KKNPP in India was fuel-loaded 12 years after the first pour of concrete as against the Rosatom's claim of a construction time of six years made before the EUR assessment team. During the 14 months of its grid connection in October 2013, the reactor worked for only 4701 hours and has been lying idle for more than half the time due to serious problems in the feed-water system, the reactor and the turbine-generator. All the seven attempts to clear the final tests for commercial commissioning failed. During the first 10 months of its grid connection, the reactor experienced 14 scrams,[12] besides a pipe burst accident in the feed-water system, leading to the hospitalisation of workers with serious musculo-skeletal and burn injuries.[13]

AES-91. In the Ermolaev presentation, the average core damage frequency for internal initiating events for the AES-91 reactor in China is 3.4 per million reactor years ($3.39x10^{-6}$a) (*Ref 2*). In a paper presented at the NEA/CSNI Workshop (Paris, in June 2011) on PSA for New and Advanced Reactors, Bo Z of the Chinese Nuclear Agency, says that the CDF of Tianwan reactor is 13 per million reactor years (1.3×10^{-5}/a).[14] The designer of the AES-2006 reactor, St Petersburg Atomenergoproekt (SPAEP), a Rosatom affiliate, makes even taller claims on the performance of the Tianwan reactor. Performance details given in a brochure[15] and from data published by IAEA PRISM[16] are given in columns 2 and 3 of table below:

	SPAEP	IAEA-PRISM
Guaranteed net power output MWe	1007	933
Effective number of hours (nominal power/year	7900	7278
Overall availability factor	92%	83%

In short, AES-91 reactors at Tianwan, China are comparable to the Gen-II reactors worldwide. The only difference is the availability of a core catcher below the Tianwan reactors. The core catcher does not reduce the chances of core meltdown; it only mitigates it – theoretically.

5. Summary

Out of the six designs in the family tree of AES-2006, the second and the third designs in have been built in China and India respectively. The Kudankulam reactor, which was show-cased for the Gen-III compliance asssessment is almost a still-born infant and its disappearance from the pedigree of AES-2006 is expected. Since no other design in the family tree has undergone the Gen-III compliance assessment, AES-2006 is just another Gen-III reactor. The following assessment of VVER-1000 reactors by WENRA is equally applicable for AES-2006:

> "The VVER-1000 plants were designed to similar safety requirements as Western plants and have equivalent safety systems. However, compared to the VVER-440/213 plants, the overall safety level of the VVER-1000 plants seems to be lower. The reason is that the higher power VVER-1000 plants have lost nearly all the inherent safety features of the smaller VVER-440 plants."[17]

Deals of about 35 AES-2006 reactors are being nogotiated between Rosatom and India, Vietnam, Bangladesh, Finland, Bulgaria, Belarus, Czech Republic and South Africa. The EUR assessment of AES-92, the dismal performance of the reactor show-cased for and certified in that assessment, Rosatom's removal of it from the genealogy of AES-2006, and the fictitious claims about the AES-91 reactor in China worthy of a detailed study. The people of the buyer-countries and those who will be the downwinders and downstreamers in the case of leaks or accidents have a right to know the truth and a duty to ensure that these ventures do not threaten the biosphere with unacceptable levels of contaminations.

Acknowledgement

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Main safety functions. Emergency reactor shutdown and its maintaining in subcritical condition. SAFETY SYSTEMS Reactor control and emergency. shutdown system. Emergency boron injection system.Â reactor cooling down in emergency situations related with depressurization of the primary circuit including rupture of the main circulation pipeline (through intact loops). 12. Design options for VVER-TOI - ÐœÐžÐ¥-Fuel. The proposed fuel handling concept and the solutions accepted in the VVER-TOI design make it possible to provide the following in case of the MOX-fuel use: Ã¼ not to rework the fresh.Â VVER-TOI -1st stage ECCS hydro accumulators have been moved below the service elevation. VVER-TOI â€" â€œmirror layoutâ€. 15. The AES-2006 is a pressurized water reactor with an output of approximately 1,200 MWe marketed by the Russian Rusatom Overseas CJSC company. There are two dif-ferent development versions of the AES-2006 plant: AES-2006/V392M and AES-. N.B. This is an unofficial translation. Original: http://www.stuk.fi/ydinturvallisuus/ydinvoimalaitosten-toiminta/uudet_laitosyksikot/fi_FI/uudet_laitosyksikot/_files/91804839551317346/default/alustava-turvallisuusarvio-liite1-laitosvaihtoehto.pdf.Â The secondary circuit is essentially the same as in the existing VVER type pressurized water reactors. Assessment and verification of safety (government decree 717/2013, section 3). Deterministic analysis methods and preliminary results. General Designer of AES-2006: The Joint Stock Companyâ€™s â€œEast-European leading scientific research and design institute for energy technologiesâ€ branch â€œSPbAEPâ€. Chief Designer of the reactor plant: JSC OKB Â«GIDROPRESSÂ». Scientific Supervisor for the Design: National Research Centre Â«Kurchatov InstituteÂ».Â Coolant flow through the reactor, m3/h Coolant temperature at reactor inlet/outlet, Nominal steady-state pressure at core outlet (abs.), MPa. Basic parameters of the secondary circuit Turbine: Rotation frequency, 1/s Design scheme Nominal steam pressure at turbine inlet, MPa Feedwater temperature under nominal conditions, ÂºC Generator: Rated voltage, kV. The design of AES-2006 of Generation 3+ with V-491 reactor plant is an evolutionary development of the designs with the VVER-1000 water cooled and water moderated reactor proved by a long-time operation. The AES-2006 design is based on the principle of safety assurance for the personnel, population and environment. The principle meets the requirements for the standards of radioactive substance releases into the environment and their content at normal operation, at anticipated operational occurrences including the design basis conditions (i.e. design events of Category 1-4) as well as at the be