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AN INNOVATIVE NUCLEAR REACTOR AS A SOLUTION TO GLOBAL WARMING

Robson Silva da Silva and Farhang Sefidvash

Nuclear engineering Department, Federal University of Rio Grande do Sul,
Av. Osvaldo Aranha, 99 – 4° andar
90046-900 Porto Alegre, RS, Brazil
robsonsilvadasilva@gmail.com

ABSTRACT

The problem of global warming is no longer a philosophical discussion, but it is a fact seriously threatening the future of humanity. In this paper a practical solution to the problem of global warming resulting from the fossil fuelled energy suppliers is presented. The energy conservation and alternative forms of energy such as solar, wind, and bio even though having important roles, do not satisfy the energy demand generated by an increasing world population that desires to increase its standard of living. The fission process in the nuclear reactors does not produce greenhouse gases that cause global warming. The new paradigm in nuclear energy is the future innovative reactors that meet the new standards set by the INPRO Program of the IAEA. One such a reactor is presented in this paper, namely the Fixed Bed Nuclear Reactor (FBNR) that is supported by the International Atomic Energy (IAEA) in its program of Small Reactors Without On-Site Refuelling (SRWOSR), being one of the four water cooled reactors in this program. The other three reactor concepts are PFPWR50 of Japan, BWR-PB of Russia and AFPR-100 of USA. It is shown that the nuclear energy of the future is totally different than what is today in respect to safety, economics, environmental impact and proliferation. In this manner, the public perception of nuclear energy will change and its acceptability is promoted.

1. INTRODUCTION

The recently held UN panel on global warming made impressive observations: “As the scientific consensus on global warming grows, it's time to look more closely at how to share the economic, social, and humanitarian burdens that climate change will likely bring. If sea levels rise at the rates they are predicting, we may see hundreds of millions of refugees. Where will they go? Who will take them in? What does it mean about immigration regulations? These were only some of the moral and ethical questions that are being posed by the looming effects of global warming. The future will be catastrophic for all communities, for all countries, but particularly for those who have already been identified as particularly vulnerable to the impacts of climate change. Some forecasts suggest that small island states will disappear entirely under the rising ocean. This is the time to remind the international community that ethics and morality do play a very important role in any human activity, especially when we have a situation where climate change is affecting such a large number, especially the poor and vulnerable”.

The solution to the problem of global warming lays both in the processes of energy conservation and energy production. None of the energy resources alone is a panacea. The solution to the ever increasing demand for energy to satisfy the needs of growing world population and improving its standard of living lies in the combined utilization of all forms of energy. Nuclear energy produced safely will have an important role in solving the world energy problem without producing greenhouse gases. The public objections to nuclear energy most often expressed are reactor safety, cost and nuclear waste disposal.

2. ENERGY AND TEMPERATURE REQUIREMENTS

About 30% of the world's primary energy consumption is used for electricity generation, about 15% is used for transportation, and the remaining 55% is converted into hot water, steam and heat. Non-electric applications include desalination, hot water for district heating, and heat energy for petroleum refining, for the petrochemical industry, and for the conversion of hard coal or lignite. For non-electric applications, the specific temperature requirements vary greatly. Hot water for district heating and heat for seawater desalination require temperatures in the 80 to 200 °C range, Temperatures in the 250 to 550 °C range are required for petroleum refining processes. Water-cooled reactors can provide heat up to about 300 °C.

3. INHERENT AND PASSIVE SAFETY

It is very desirable to develop concepts of inherently safe nuclear reactors whose safety features are easily demonstrable without depending on the interference of active safety devices which have some probability of failing, or on operator skills and good judgment, which could vary considerably.

There are only four significant sources of energy in a reactor accident: Nuclear power excursion, Thermal reactions (steam explosion), Chemical reactions (zirconium/water and core/concrete), and Radioactive decay heat. The first three can be limited or controlled by proper selection of materials - a form of inherent safety. The fourth energy source, decay heat, is a slow and inherently restricted form of energy release.

All current reactors need to include safety systems to remove decay or residual heat produced after the chain reaction in a reactor has ceased. It is this decay heat that threatens to produce the most serious of nuclear accidents namely the core melt. The inherently safe reactors are transparently incapable of producing a core melt. They are "forgiving" reactors, able to tolerate human and mechanical malfunctions without endangering public health. Also they are called "walk away" reactors as the key feature of these reactors is their reliance upon passive or non-mechanical, safety systems.

4. INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO)

The objective of INPRO is to support the safe, sustainable, economic and proliferation-resistant use of nuclear technology to meet the global energy needs of the 21st century. The International Atomic Energy Agency has committed itself to "Help to ensure that nuclear energy is available to contribute in fulfilling energy needs in the 21st century in a sustainable manner; and to bring together both technology holders and technology users to consider jointly the international and national actions required to achieve desired innovations in nuclear reactors and fuel cycles".

5. A NEW NUCLEAR REACTOR CONCEPT

A new small inherently safe nuclear reactor concept, namely the Fixed Bed Nuclear Reactor

(FBNR) concept is being developed under the support of the International Atomic Energy (IAEA) under its program of Small Reactors Without On-Site Refuelling (SRWOSR). The reactor uses the light water reactor technology. It fulfills the objectives of design simplicity, inherent and passive safety, economy, standardization, shop fabrication, easy transportability and high availability. The inherent safety characteristic of the reactor dispenses with the need for containment; however, a simple underground containment is envisaged for the reactor in order to reduce any adverse visual impact.

5.1 Reactor Description

The Fixed Bed Nuclear Reactor (FBNR) is a small reactor (40 MWe) without the need of on-site refueling. It utilizes the PWR technology but uses the HTGR type fuel elements. It has the characteristics of being simple in design, modular, inherent safety, passive cooling, proliferation resistant, and reduced environmental impact.

The FBNR is modular in design, and each module is assumed to be fuelled in the factory. The fuelled modules in sealed form are then transported to and from the site. The FBNR has a long fuel cycle time and, therefore, there is no need for on-site refuelling. The reactor makes an extensive use of PWR technology.

It is an integrated primary system design. The basic modules, as shown in the schematic figure, have in its upper part the reactor core and a steam generator and in its lower part the fuel chamber. The core consists of two concentric perforated zircaloy tubes of 20 cm and 160 cm in diameters, inside which, during the reactor operation, the spherical fuel elements are held together by the coolant flow in a fixed bed configuration, forming a suspended core. The coolant flows vertically up into the inner perforated tube and then, passing horizontally through the fuel elements and the outer perforated tube, enters the outer shell where it flows up vertically to the steam generator. The reserve fuel chamber is a 40-cm diameter tube made of high neutron absorbing alloy, which is directly connected underneath the core tube. The fuel chamber consists of a helical 25 cm diameter tube flanged to the reserve fuel chamber that is sealed by the international authorities. A grid is provided at the lower part of the tube to hold the fuel elements within it. A steam generator of the shell-and-tube type is integrated in the upper part of the module. A control rod slides inside the centre of the core for fine reactivity adjustments. The reactor is provided with a pressurizer system to keep the coolant at a constant pressure. The pump circulates the coolant inside the reactor moving it up through the fuel chamber, the core, and the steam generator. Thereafter, the coolant flows back down to the pump through the concentric annular passage. At a certain pump velocity, the water coolant carries up the 15 mm diameter spherical fuel elements from the fuel chamber into the core. A fixed suspended core is formed in the module. In a shut down condition, the suspended core breaks down and the fuel elements leave the core and fall back into the fuel chamber. The fuel elements are made of TRISO type micro spheres used in HTGR.

Any signal from any detector due to any initiating event is assumed to cut-off power from the pump, causing the fuel elements to leave the core and fall back into the fuel chamber, where they remain in a highly sub critical and passively cooled condition. The fuel chamber is cooled by natural convection transferring heat to the water in the tank housing the fuel chamber.

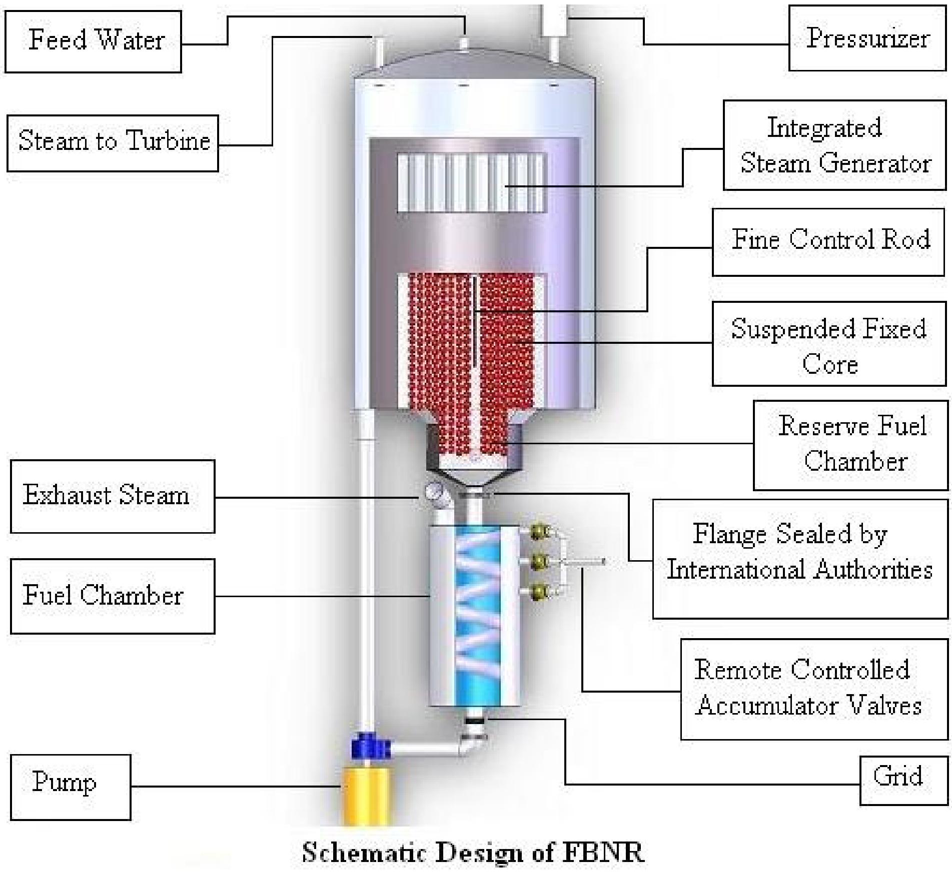

Figure 1. Schematic Design of the Fixed Bed Nuclear Reactor (FBNR).

5.2 Some Of The Characteristics Of The Proposed Reactor

The Fixed Bed Nuclear Reactor is based on the pressurized light water reactor (PWR) technology. It is a small reactor and simple in design.

5.3 FBNR is an Inherently Safe and Passively Cooled Reactor.

The spherical fuel elements of HTGR type are fixed in the suspended core by the flow of water coolant. Any malfunction in the reactor system will cut off the power to the coolant pump causing a stop in the flow. This results in making the fuel elements fall out of the reactor core by the force of gravity and become stored in the passively cooled fuel chamber under sub critical condition.

Its spent fuel is in such a convenient form and size that may be utilized directly as the source for irradiation and applications in agriculture and industry. This feature results in a positive impact on waste management and environmental protection.

The spent fuel from FBNR is in a form and size (15 mm dia. spheres) that can directly be used as a source of radiation for irradiation purposes in agriculture and industry. Therefore, The spent fuel from FBNR may not be considered as waste, in a peaceful world of the future, as it can perform useful functions. Should reprocessing not be allowed, the spent fuel elements can easily be vitrified in the fuel chamber and the whole chamber be deposited directly in a waste repository. These factors result in reduced adverse environmental impact.

5.4 Diversity of Applications

The FBNR is a land-based nuclear power plant for urban or remote localities. The FBNR is designed to produce electricity alone or to operate as a cogeneration plant producing simultaneously: electricity, desalinated water, steam for industrial purposes and heat for district heating. A MultiEffect Distillation (MED) plant may be used for water desalination.. An estimated 1000 m3/day of potable water could be produced at 1 MW(e) reduction of the electric power.

5.5 It is a Fool Proof Non-Proliferation Resistant Reactor.

Under the present world conditions, the first priority of the governments in relation to nuclear energy is non- proliferation and safeguard of the nuclear reactors. This provides a challenge for nuclear technologists to come up with a fool proof nuclear reactor concept.

The IAEA - INPRO recommends that: "Both intrinsic features and extrinsic measures are essential, and neither should be considered sufficient by itself. Extrinsic proliferation resistance measures, such as control and verification measures will remain essential, whatever the level of effectiveness of intrinsic features. From a proliferation resistance point of view, the development and implementation of intrinsic features should be encouraged".

The non-proliferation characteristics of FBNR is based on both The extrinsic concept of sealing and The intrinsic concept of isotope denaturing. The small spherical fuel elements are confined in a fuel chamber that can be sealed by the international authorities for inspection at any time. Only the fuel chamber is needed to be transported from the fuel factory to the site and back. Therefore, both concepts of "sealing" and "isotope denaturing" contribute to the fool proof non-proliferation characteristics of FBNR.

5.6 No Need for On-Site Refueling

The reactor's fuel chamber is fuelled in the factory. The fuel chamber is sealed by the international safeguard authorities. The FBNR can have a very long fuel cycle time depending on the projected size of reserve fuel chamber. The core life is decided according to the user's need. No refueling on the site is necessary because the fuel elements are always in the sealed fuel chamber and transported to and from the factory for refueling under surveyed condition. Refuelling is done by the replacement of fuel chamber. The length of the fuel cycle chosen depends on the economic analysis of the fuel inventory for particular situation of the reactor and its application. The FBNR fuel elements have high burn up capacity.

The size of reserve fuel chamber can be adapted to the need. The replacement of fuel chamber is done at any desired time interval and could be set at every 10 years or for the reactor lifetime.

No reshuffling of fuel is necessary because the fuel elements go from fuel chamber to the core and back without the need of opening the reactor.

There is no need for fresh fuel to be stored at the reactor site since the sealed fuel chamber is transported to and from the factory where the refueling process is performed. The spent fuel are confined in the sealed fuel chamber and kept cool by its water tank. It can be sent back to the factory at any time when the radiological requirements are met. No unauthorized access to the fresh or spent fuel is possible because the fuel elements are either in the core or in the fuel chamber under sealed condition . Therefore, no clandestine diversion of nuclear fuel material is possible.

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