SUSTAINABLE MINIREACTORS: A FRAMEWORK FOR DECENTRALIZED NUCLEAR ENERGY SYSTEMS

A.A. Harms
McMaster University, Hamilton, Ontario (Canada)

W.W. Sassin
Energy Systems Program, International Institute for Applied Systems Analysis, Laxenburg (Austria)

ABSTRACT

The concept of a nuclear energy system consisting of numerous small, specialized nuclear reactors providing heat or electricity for localized/regional purposes is considered. It is envisaged that a "parent" nuclear facility would sustain the fuel needs of many small nuclear energy "satellites" and possibly provide other fuel-management services. The choice of fuel cycle and the operational features of these satellites may be determined by the form of energy required, public and social preferences, and institutional factors. Three distinct classes of distributed systems, each based on extensions of existing nuclear technology, are identified and discussed.

1 INTRODUCTION

The current civilian nuclear power program has developed with a dominant emphasis on the development of large central-station electricity-producing power plants in the 2000–5000 MWth range. While the need to serve correspondingly large and interconnected grids is generally evident, it is also recognized that there exists a need for small power sources serving localized and special energy requirements.

We consider here a nuclear energy system consisting of numerous small minireactors in the 1–10 MW capacity range. Such small nuclear reactors could supply energy for small isolated communities, localized industrial activity, apartment buildings, and institutional centers such as schools and small hospitals. These minireactors would therefore need to operate safely with high reliability and, as we emphasize here, be assured of a sustainable supply of easily transportable fuel. A central nuclear "parent" facility is envisaged for this latter purpose.

By separating "fuel-supply" facilities from "fuel-burning" facilities, optimization with regard to safety and reliability may be imposed as well as adaptability to siting and technological considerations.

G. S. Bauer et al. (eds.), *Nuclear Technologies in a Sustainable Energy System*

2 NUCLEAR SYNERGISM

In order to develop the minireactor systems concept we refer briefly to the underlying concept of nuclear energy synergism (Harms, 1980; Harms and Häfele, 1981). By this term we imply the integrated operation of distinct nuclear processes and separate nuclear energy components so that the total system displays advantages that are not possible otherwise. Nature provides many examples of synergism whereby one component in an ecological cycle provides a feedstock for another. Man-made systems, if suitably designed and efficiently integrated, may similarly display synergetic characteristics.

The concept of synergism may be illustrated by reference to a general exoergic nuclear reaction

$$\mathrm{A} + \mathrm{B} \rightarrow \sum_i R_i + Q \tag{1}$$

Here A and B are selected nuclei or nucleons and R_i is one of several reaction products; Q is the energy released in the process to be recovered. Both fission and fusion reactions are special cases of such reactions.

Nuclear synergism can be realized if the reaction products serve an added and dominant energy-producing process. By general extension of eqn. (1), we conceive two distinct possibilities: one is

$$\begin{array}{l} \mathrm{A} + \mathrm{B} \rightarrow \mathrm{C} + \mathrm{D} \\ \qquad\quad \downarrow \\ \qquad\quad \mathrm{C} + \mathrm{A} \rightarrow Q + \ldots \end{array} \tag{2}$$

in which one of the reaction products combines with one of the initial reactants to generate energy. The second case

$$\begin{array}{l} \mathrm{A} + \mathrm{B} \rightarrow \mathrm{C} + \mathrm{D} \\ \qquad\qquad\quad \downarrow \\ \qquad\qquad\quad \mathrm{D} + \mathrm{E} \rightarrow Q + \ldots \end{array} \tag{3}$$

is one in which a reaction product is able to combine with another readily available nucleus or nucleon to release significant amounts of energy.

These two examples will be used in the following discussion in which a "parent" process maintains the first parts of eqns. (2) and (3) while the second parts of these equations occur in "satellite" processes.

3 AN ACCELERATOR–FISSION SYSTEM

When a sufficiently energetic proton strikes a heavy nucleus a significant number of nucleons may be released; these emitted nucleons may excite other nuclei in the target,