Bahman Zohuri

Nuclear Micro Reactors

Springer

Nuclear Micro Reactors

Bahman Zohuri

Nuclear Micro Reactors

Springer

Bahman Zohuri
Galaxy Advanced Engineering
Albuquerque, NM, USA

ISBN 978-3-030-47224-5 ISBN 978-3-030-47225-2 (eBook)
https://doi.org/10.1007/978-3-030-47225-2

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2020
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to my son Sash, my grandson Dariush and my granddaughter Donya.

Preface

A new generation of reactors will start producing power in the next few years. They are comparatively tiny—and may be key to hitting our climate goals for the better, free of carbon emissions and free from greenhouse effects.

For the last 20 years, the future of nuclear power has stood in a high bay laboratory tucked away on the Oregon State University campus in the western part of the state. Operated by NuScale Power in the form of Small Modular Reactors (SMR), an Oregon-based energy startup, this prototype reactor represents a new chapter in the conflict-ridden, politically bedeviled saga of nuclear power plants. Or even old companies such as Westinghouse with many years of experience in nuclear power plant in the form of Generation III and now with introduction of transportable Nuclear Micro Reactor eVinci, which has both space exploration into terrestrial domain and military application for a mobile brigade for a rapid deployment process.

NuScale's reactor will not need massive cooling towers or sprawling emergency zones. It can be built in a factory and shipped to any location, no matter how remote due to its modulization technical approach, and it is built around old and traditional knowledge of Light Water Reactor technique. Extensive simulations suggest that it can handle almost any emergency without a meltdown. One reason for that is it barely uses any nuclear fuel—at least compared with existing reactors.

eVinci Micro Reactor cooling system is designed and its cooling system is based on Advanced Heat Pipe technology which is a very dynamic yet as passive cooling system with most safe way without any meltdown disasters either manmade or natural threats.

NASA's approach with heat pipe cooled of kilopower reactor for space exploration and Mars mission in near future is another application of these small reactors yet big energy source for such application that allows to travel beyond terrestrial space.

This is good news for a planet in the grips of a climate crisis. Nuclear energy gets a bad rap in some environmentalist circles, but many energy experts and policymakers agree that splitting atoms is going to be an indispensable part of decarbonizing the world's electricity. In the United States, nuclear power accounts for about two-thirds of all clean electricity, but the existing reactors are rapidly approaching the end of their regulatory lifetimes. Only two new reactors are under construction in the United States, but they are billions of dollars over budget and years behind schedule.

Enter the small modular reactor designed to allow several reactors to be combined into one unit. Need a modest amount of energy? Install just a few modules. Want to fuel a sprawling city? Tack on several more. Coming up with a suitable power plant for a wide range of situations becomes that much easier. As they are small, these reactors can be mass-produced and shipped to any location in a handful of pieces. Perhaps most importantly, small modular reactors can take advantage of several cooling and safety mechanisms unavailable to their big brothers, which all but guarantee they will not become the next Chernobyl or Fukushima.

Nuclear reactors are getting smaller and this is opening up some big opportunities for the industry. A handful of micro reactor designs are under development in the United States, and they could be ready to roll out within the next decade.

These plug-and-play reactors will be small enough to transport by truck and could help solve energy challenges in a number of areas, ranging from remote commercial or residential locations to military bases.

The devastating impacts of climate change caused by burning fossil fuels are forcing countries around the world to look for zero-emissions alternatives for generating electricity.

One such alternative is nuclear energy, and the International Energy Agency—a group focused on energy security, development, and environmental sustainability for 30-member countries—says the transition to a cleaner energy system will be drastically harder without it.

Canada's government appears to be on board, saying nuclear innovation plays a "critical role" in reducing greenhouse gas emissions as Canada moves toward a low-carbon future.

While Canada Deuterium Uranium (CANDU) reactors, a Canadian design, have powered some Canadian communities for decades, the government is now eyeing technology of a different scale. The federal government describes small modular reactors (SMR), as the "next wave of innovation" in nuclear energy technology and an "important technology opportunity for Canada."

In this book, we cover a summary and overall aspect of Generation IV (GEN-IV), or they are also known as Small Modular Reactors (SMRs) as well. In this book, we also cover Nuclear Micro Reactor and its need and implementation within Department of Defense (DOD) military organizations.

Here is what you need to know about them.

What is a small modular reactor?

Traditional nuclear reactors used in Canada can typically generate about 800 MW of electricity, or about enough to power about 600,000 homes at once (assuming that 1 MW can power about 750 homes).

The International Atomic Energy Agency (IAEA), the UN organization for nuclear cooperation, considers a nuclear reactor to be “small” if it generates under 300 MW.

Albuquerque, NM Bahman Zohuri
2016

Acknowledgment

I am indebted to the many people who aided me, encouraged me, and supported me beyond my expectations. Some are not around to see the results of their encouragement in the production of this book, yet I hope they know of my deepest appreciations. I especially want to thank all my friends, to whom I am deeply indebted, have continuously given their support without hesitation. They have always kept me going in the right direction, specially a true friend Dr. Patrick J. McDaniel.

Above all, I offer very special thanks to my late mother and father, and to my children, in particular, my son Sasha, who always encouraged me while we had in this world for a short time. They have provided constant interest and encouragement, without which this book would not have been written. Their patience with my many absences from home and long hours in front of the computer to prepare the manuscript are especially appreciated.

Contents

About the Author

Bahman Zohuri currently works for Galaxy Advanced Engineering, Inc., a consulting firm that he started in 1991 when he left both the semiconductor and defense industries after many years working as a chief scientist. After graduating from the University of Illinois in the field of physics, applied mathematics, then he went to the University of New Mexico, where he studied nuclear engineering and mechanical engineering. He joined Westinghouse Electric Corporation, where he performed thermal hydraulic analysis and studied natural circulation in an inherent shutdown heat removal system (ISHRS) in the core of a liquid metal fast breeder reactor (LMFBR) as a secondary fully inherent shutdown system for secondary loop heat exchange. All these designs were used in nuclear safety and reliability engineering for a self-actuated shutdown system. He designed a mercury heat pipe and electromagnetic pumps for large pool concepts of an LMFBR for heat rejection purposes for this reactor around 1978, when he received a patent for it. He was subsequently transferred to the defense division of Westinghouse, where he oversaw dynamic analysis and methods of launching and controlling MX missiles from canisters. The results were applied to MX launch seal performance and muzzle blast phenomena analysis (i.e., missile vibration and hydrodynamic shock formation). Dr. Zohuri was also involved in analytical calculations and computations in the study of nonlinear ion waves in rarefying plasma. The results were applied to the propagation of the so-called soliton waves and the resulting charge collector traces in the rarefaction characterization of the corona of laser-irradiated target pellets. As part of his graduate research work at Argonne National Laboratory, he performed computations and programming of multi-exchange integrals in surface physics and solid-state physics. He earned various patents in areas such as diffusion processes and diffusion furnace design while working as a senior process engineer at various semiconductor companies, such as Intel Corp., Varian Medical Systems, and National Semiconductor Corporation. He later joined Lockheed Martin Missile and Aerospace Corporation as Senior Chief Scientist and oversaw research and development (R&D) and the study of the vulnerability, survivability, and both radiation and laser hardening of different components of the Strategic Defense Initiative, known as Star Wars.

This included payloads (i.e., IR sensor) for the Defense Support Program, the Boost Surveillance and Tracking System, and Space Surveillance and Tracking Satellite against laser and nuclear threats. While at Lockheed Martin, he also performed analyses of laser beam characteristics and nuclear radiation interactions with materials, transient radiation effects in electronics, electromagnetic pulses, system-generated electromagnetic pulses, single-event upset, blast, thermo-mechanical, hardness assurance, maintenance, and device technology.

He spent several years as a consultant at Galaxy Advanced Engineering serving Sandia National Laboratories, where he supported the development of operational hazard assessments for the Air Force Safety Center in collaboration with other researchers and third parties. Ultimately, the results were included in Air Force Instructions issued specifically for directed energy weapons operational safety. He completed the first version of a comprehensive library of detailed laser tools for air-borne lasers, advanced tactical lasers, tactical high-energy lasers, and mobile/tactical high-energy lasers, for example.

He also oversaw SDI computer programs, in connection with Battle Management C^3I and artificial intelligence, and autonomous systems. He is the author of several publications and holds several patents.

Chapter 1
Nuclear Micro Reactors: The Next Wave of Innovation

1.1 Introduction

Growth of population globally has direct impact on demand for energy. Almost 18% growth in population and their required daily life on energy and electricity demand presents a different dimension for production of electricity not only from renewable perspective, but also puts nuclear energy resource in different category. New generation of nuclear reactors in the form of Small Modular Reactors (SMRs) or GEN-IV. With new safety factors built into these reactors, with better thermal efficiency output with innovative approach to Combined Cycle (CC) makes them more cost-effective from Return On Investment (ROI) point of view [1–3].

Furthermore, the presence of new renewable technology and suggested solutions by expert in the field for source of energy and energy storage does not eliminate a demand and need for both present and near-term *Nuclear Fission Reactors* in the form of GEN-III (i.e., present) to GEN-IV (i.e., next generation of SMRs) to Nuclear Fusion Reactors in far term.

The rule of thumb for generating electricity is falling into the following category. The requirement for production of electricity is that the electricity generation rate at all times equals the demand for electricity. Economically achieving this goal is easy with fossil fuels because the primary cost of producing electricity is the cost of the fuel, not the cost of the power plant. It is economically viable to operate a fossil plant at part load. As a consequence, in the USA and much of the world the preferred fossil-fuel generating technology is the Gas Turbine Combined Cycle (GTCC)—a low cost machine with rapid response to variable electricity demand with heat-to-electricity efficiencies above 60% [1, 2].

The major growth in the electricity production industry in the last 30 years has centered on the expansion of natural gas power plants based on gas turbine cycles. The most popular extension of the simple Brayton gas turbine has been the combined cycle power plant with the air-Brayton cycle serving as the topping cycle and

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2020
B. Zohuri, *Nuclear Micro Reactors*, https://doi.org/10.1007/978-3-030-47225-2_1