Nuclear Power: Volume III - The Future of Nuclear Power

An Online Continuing Education Course for Engineers

Course Number: R-3005

Credit: 3 Hours / 3 PDH / 3 CPD

Nuclear Power: Volume III – The Future of Nuclear Power

Lee Layton, P.E.

Cover photograph: Courtesy U.S. Nuclear Regulatory Commission (NRC).

Preface

This is the third in a series of three courses about the nuclear power industry.

The series covers the nuclear industry from the physics of nuclear reactions to the types of plants in operation today as well as the potential of the next generation of nuclear power plants that are likely to appear in the first half of the 21st century.

The complete series includes three courses:

1. Volume I – The Nuclear Power Industry
2. Volume II – Nuclear Power Plants
3. Volume III – The Future of Nuclear Power

The first course, *Volume I – The Nuclear Power Industry*, gives a broad overview of the nuclear power industry. This course goes into the details of nuclear reactions and the physics of nuclear power. The prime fuel source, uranium, is covered too.

The second course, *Volume II – Nuclear Power Plants*, reviews the classifications of nuclear power plants and the basic components of a nuclear power plant. The course covers the design and operation of the current generation of nuclear power plants in operation today.
The third course, *Volume III – The Future of Nuclear Power*, gives an overview of the types of plants that are being considered for the next generation of power plants. Some of the designs covered are already operating in experimental stages, some are modifications of current designs, and others are radical new concepts that have not been commercially validated.
It is not necessary to take the courses in sequence. However, for the best comprehensive it is suggested that the courses be taken in the order presented.

Introduction

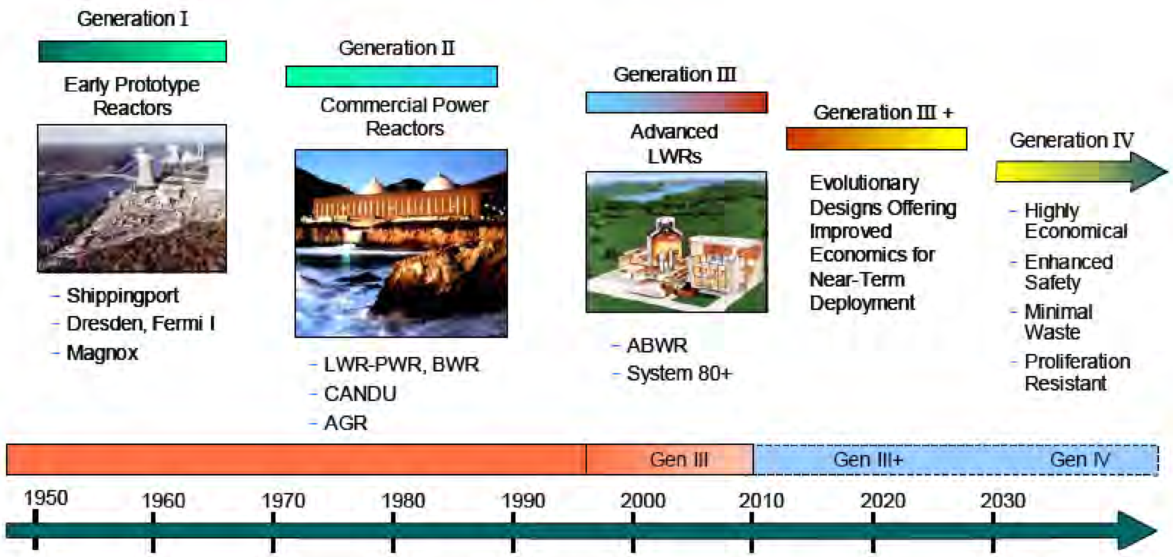
The world's population is expected to expand from about 6 billion people to 10 billion people by the year 2050, all striving for a better quality of life. As the Earth's population grows, so will the demand for energy and the benefits that it brings: improved standards of living, better health and longer life expectancy, improved literacy and opportunity, and many others.

Many of the world's nations, both industrialized and developing, believe that a greater use of nuclear energy will be required if energy security is to be achieved. They are confident that nuclear energy can be used now and in the future to meet their growing demand for energy safely and economically, with certainty of long term supply and without adverse environmental impacts.

Approximately 16% of world electric demand is served from 449 nuclear power plants with a capacity of 391 GW. The United States produces the most nuclear energy, with nuclear power providing 19% of the electricity it consumes, while France produces the highest percentage of its electrical energy from nuclear reactors—72% as of 2017. It is quite possible to utilize nuclear power to provide the vast majority of an entire country's need for electricity.

This course is the third in a series about the use of nuclear energy to generate electricity. Volume I in this series included an overview of the nuclear industry and covered the basics of nuclear physics and uranium as a fuel source and Volume II delved into the specific types of nuclear reactors in use around the world today.

The current generation of commercial nuclear power plants are known as Generation II reactors (the earliest experimental reactors are classified as Generation I reactors.) Generation III plants are, for the most part, improved versions of Generation II plants and are near term ready for commercialization. See the timeline below.



Generation IV nuclear reactors will be revolutionary new designs that the industry hopes will be very economical and efficient. These reactors will likely not appear until at least 2020.

In this course, we will start with a brief overview of the current crop of Gen-III plants that are likely to be seen in commercial operation in the next few years. Subsequent chapters will cover several of the promising Gen-IV reactors. There are currently six Gen-IV reactors that hold significant promise. They are:

- Very High Temperature Reactor (VHTR)
- Supercritical-Water-Cooled Reactor (SCWR)
- Molten-Salt Reactor (MSR)
- Gas-Cooled Fast Reactor (GFR)
- Sodium-Cooled Fast Reactor (SFR)
- Lead-Cooled Fast Reactor (LFR)

Let's look at Chapter One for an overview of the Gen-III reactors.

Chapter 1
Generation III Reactors

This chapter covers a few of the evolutionary designs that are basically improvements on existing commercially operating nuclear reactors. These units may be in operation in the early 2020's. The units covered in the chapter include the Westinghouse AP1000, The EPR, and Hyperion Power Module. There are other Generation III reactors that are not included in this discussion.

AP1000

Westinghouse Electric Company's AP1000 reactor design is the first Generation III reactor to receive final design approval from the Nuclear Regulatory Commission (NRC.) It is an evolutionary improvement on the currently operating AP600. It is essentially a more powerful model with roughly the same land use. The AP1000 is a two-loop PWR planned to produce a net 1,154 MW.

Reaction: Fission

Moderator: Water

Coolant: Water

The design is less expensive to build than other Gen-III plants partly because it uses existing technology. The design also decreases the number of components, including pipes, wires, and valves. Standardization and type-licensing should also help reduce the time and cost of construction. Because of its simplified design compared to current generation PWR's, the AP1000 has:

- 50% fewer safety-related valves
- 35% fewer pumps
- 80% less safety related piping
- 85% less control cable
- 45% less building volume

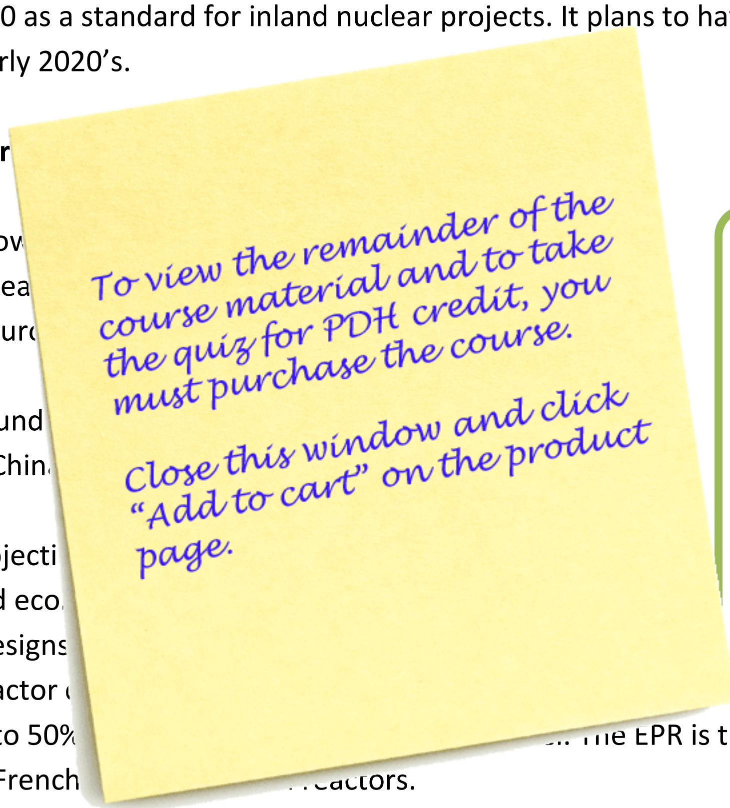
Like existing PWR's, the refueling cycle is 18 - 24 months.

The Nuclear Regulatory Commission approved the final design certification for the AP1000. This means that prospective builders can apply for a Combined Construction and Operating License (COL) before construction starts, whose validity is conditional upon the plant being built as designed.

In this design Westinghouse's Passive Core Cooling System (PCCS) uses less than twenty explosively operated valves which operate within the first 30 minutes of an incident, even if the reactor operators take no action. The electrical system required for initiating the passive systems doesn't rely on external or diesel power and the valves don't rely on hydraulic or compressed air systems. If the active process to turn on the passive system works, the design is intended to passively remove heat for 72 hours, after which the PCS gravity drain water tank must be topped up for as long as cooling is required.

The first commercially operated AP1000 reactors will likely be in China. China has officially adopted the AP1000 as a standard for inland nuclear projects. It plans to have the first units in operation in the early 2020's.

Evolutionary Power



The Evolutionary Pow
pressurized water rea
initially called the Eur

Four EPR units are und
France and two in Chin

The main design objecti
providing enhanced eco
to previous PWR designs
1,650 MW. The reactor
optionally with up to 50% ... The EPR is the evolutionary
descendant of the French ... reactors.

Reaction: Fission

Moderator: Water

Coolant: Water

The EPR design has several active and passive protection measures against accidents. There are four independent emergency cooling systems, each capable of cooling down the reactor after shutdown.   Leak tight containment is provided around the reactor.   And there is an extra container and cooling area if a molten core manages to escape the reactor.   In addition, there is a two-layer concrete wall, designed to withstand impact by airplanes and internal overpressure.

It has been stated that the EPR is the only new reactor design under consideration in the United States that "...appears to have the potential to be significantly safer and more secure against attack than today's reactors."