MODULAR INTEGRAL COMPACT UNDERGROUND REACTOR

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INTRODUCTION

An integral compact nuclear reactor that is smaller in size than a rail car and that costs one tenth the cost of a conventional plant is emerging as a contender in the resurgent global nuclear power industry [1]. These small power reactors designs benefit from the accumulated experience in the design and operation of naval propulsion reactors with which they share the integral and small power features.

Because they could be water-cooled or air-cooled, such compact reactors would not have to be located near large sources of water, voiding a limitation on the use of large reactors that require millions of gallons of water each day for cooling purposes.

This opens up parts of the arid USA West and other arid regions of the world for nuclear development. Underground brackish water supplies that are otherwise unusable, could be desalinated into fresh water for agricultural and municipal use [2].

An attractive feature of the prospect is that utilities could start with a few reactors and add more units as needed. By contrast, with large reactor units, utilities have what is called in the industry a "single-shaft risk," where billions of dollars are tied up in a single plant.

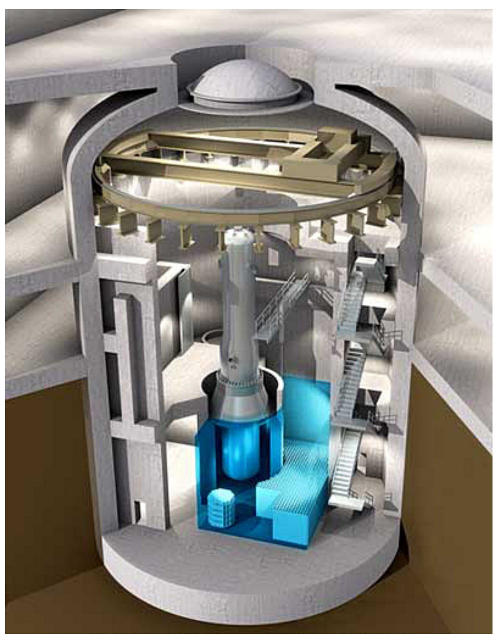

Figure 1. Schematic of modular mPower compact underground reactor. Source: Babcock & Wilcox.

Yet, another advantage is that these reactors will store all of their waste on each site for the estimated 60-year life of each reactor. Once on site, each reactor would be housed in a two-story containment structure that would be buried beneath the ground for added security. They would remain on-line round the clock, stopping to refuel every 5 years instead of every 18 - 24 months, like existing reactors.

Three large utilities, the Tennessee Valley Authority, First Energy Corp. and Oglethorpe Power Corp., signed an agreement with Babcock & Wilcox a subsidiary of the construction and Engineering Company: McDermott International Inc., committing to get the new reactor approved for commercial use in the USA.

The reactor design possesses the following main characteristics:

1. An Integral nuclear system design,
2. The use of Passive Safety systems,
3. It operates on a 4 ½ year refueling interval,
4. It uses a 5 percent U^{235} enriched fuel,
5. It is housed in a secure underground containment system,
6. It incorporates a spent fuel pool capacity for the 60 years expected lifetime of the facility.

The Babcock & Wilcox Company (B&W) plans to deploy its B&W mPower reactor as a scalable, modular, passively safe, advanced light water reactor system. The design, with its scalable, modular feature, has the capacity to provide 125 - 750 MWe or more for a 5 year operating cycle without refueling, and is designed to produce near-zero emission operation.

A newly formed entity, B&W Modular Nuclear Energy, LLC, leads the development, licensing and delivery of B&W mPower reactor projects.

The Babcock & Wilcox's Company roots go back to 1867 and it has been making equipment for utilities since the advent of electrification, furnishing boilers to Thomas Edison's Pearl Street generating stations that brought street lighting to New York City in 1882. Based in Lynchburg, Virginia, the company has been building small propulsion reactors since the 1950s. In addition to reactors for the USA Navy submarines and aircraft carriers, it built a reactor for the USS NS Savannah, a civilian commercial vessel. It is now moored as a floating museum in the Baltimore harbor. It also built eight large reactors, , including one for the two units Three Mile Island plant.

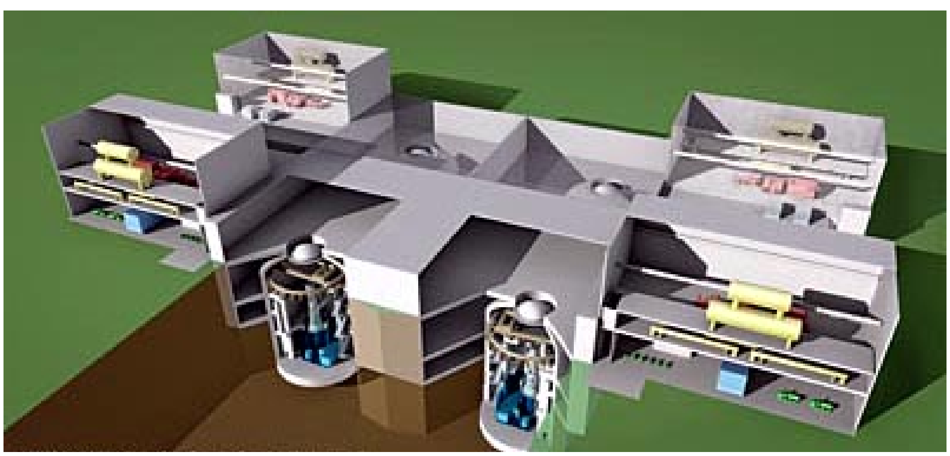

Figure 2. Compact Underground Reactor in a 4 units 500 MWe configuration of 125 MWe each. Source: Babcock & Wilcox.

Figure 3. Integral configuration of core and steam generator within the reactor vessel of the modular reactor. Source Babcock & Wilcox.

MAIN FEATURES

The compact modular Babcock & Wilcox reactor can generate only 125 - 140 MWe of power. This is about 1/10 the standard capacity of the larger 1,000 MWe capacity.

The USA utilities are betting that these smaller, simpler reactors can be manufactured quickly and installed at potentially dozens of existing nuclear sites or replace coal-fired plants that may become obsolete with looming emissions restrictions.

The emerging interest in small reactors illustrates a growing unease with the route that nuclear power has taken for half a century. The first commercial reactor built in the USA in 1957 at Shippingport, Pennsylvania, had only a 60 MWe capacity. Three decades later, invoking the economies of size, reactors had grown progressively bigger, ending up at about at the 1,000 MWe of capacity.

A standard modular reactor unit generates 125 MWe of power. It is 75 feet in height and 15 feet in diameter.

The core assembly consists of 69 fuel assemblies to be replaced as a whole after 4-5 years. It is surrounded by an underground containment dome that encloses the nuclear reactor and steam generator.

The Steam Generator uses an integral technology adopted from naval reactors technology. It is not a separate component like in conventional reactor designs. It is instead incorporated into the reactor's core.

A crane is used to replace the core assembly during refueling or move any heavy components that need replacement. A water pool surrounds the reactor vessel to store the unused as well as the spent fuel assemblies for the 60 years lifespan of the plant.

The scalable design offers flexibility so that multiple reactor modules can be aggregated to support a local utility requirements and infrastructure constraints.

TECHNICAL DESCRIPTION

The optimized Advanced Light Water Reactor (ALWR) of the Pressurized Water Reactor (PWR) type, is presented as a Generation III++ nuclear technology that can be certified, manufactured and operated within the existing USA regulatory domestic industrial supply chain and utility operational infrastructure.

The modular and scalable design of the B&W mPower reactor allows B&W to match the generation needs with the proven performance of existing light water reactor technology. Each B&W mPower reactor that is brought online will contribute to the reduction of approximately 57 million metric tons of CO_2 emissions over the life of the reactor. Its technical specifications encompass:

1. Flexibility and scalability to local power needs with 1-10 multi units plants,
2. Integrated design reactor modules,
3. Accepted ALWR, PWR concepts,
4. The use of a Passive safety system,
5. Shop manufactured with no on-site Nuclear Steam Supply System (NSSS) construction,
6. A short 3-year construction cycle,

The Integral simplified NSSS includes:

1. An internal steam generator,
2. No need for safety-grade backup power,
3. No need for an external pressurizer,
4. The use of conventional core and standard fuel,
5. No credible large pipe break Loss of Coolant Accident (LOCA),

Its offers simplified operations and maintenance through:

1 A 4 ½ year replacement core design,
2. Sequential partial-plant outages providing a high capacity factor,
3. A standardized balance of plant.

DISCUSSION

For utilities, a small reactor has several advantages, starting with cost. Small reactors are expected to cost about $5,000 per kWe of installed capacity, or about $125x10^3$ x 5,000 = $625 million for a single 125 MWe unit.

For a combined 500 MWe, four units installation as shown if Fig. 2, the total cost would be 4 x 625 = $2.5 billion.

In comparison, large reactors cost $5 billion to $10 billion for reactors that would range from 1,100 to 1,700 MWe of generating capacity.

The first units likely would be built adjacent to existing nuclear plants, many of which were originally permitted to have 2-4 units but usually have only one or two. An example is the Clinton Power Plant in Illinois that operates a single BWR unit with space available next to it for a second unit.

In the future, the nuclear and fossil fuel generation utilities could replace existing nuclear and coal-fired power plants with compact reactors in order to take advantage of sites already served by transmission lines and, in some cases, needed for grid support. Like any other power plants, these small reactors could be easily hooked up to the power grid.

The most prominent attraction of the prospect is that utilities could start with a few reactors and add more units as needed. By contrast, with large reactor units, utilities have what is called in the industry a "single-shaft risk," where billions of dollars are tied up in a single plant.

Another advantage is that reactors will store all of their waste on each site for the estimated 60-year design lifetime of each reactor.

The slow pace of nuclear power development mandates that the next wave of large reactors would not begin coming on line until the 2016 – 2017 period. The first certification request for a small reactor design is expected to be Babcock & Wilcox's request in 2013. The first units could come on line after 2018. However, as some experts believe that if the USA utility industry embraces small reactors, nuclear power in the USA could become pervasive because more utilities would be able to afford them.

Small reactors should be as safe, or safer, than large ones. A reason is that they are simpler in design and operation and have fewer moving parts that are prone to failure. Small reactors produce less decay heat power per unit making it easier to shut them down, should a malfunction occur. With a large reactor, the response to a malfunction tends to be quick, whereas in smaller ones, they respond more slowly which makes them easier to control.

Once on site, each reactor would be housed in a two-story containment structure that would be buried beneath the ground for added security. They would run round the clock, stopping to refuel every five years instead of 18 to 24 months, like existing reactors.

The compact reactors promise fewer jobs than a large plant, which offers 700 - 1,000 permanent jobs. Small plants satisfy the same security and safety standards as large plants but would require a smaller work force because they would run much longer between their refueling and maintenance outages.

REFERENCES

1. Rebecca Smith, “Small Reactors Generate Big Hopes,” The wall Street Journal, Business, February 18, 2010.

2. Magdi Ragheb, “Nuclear, Plasma and Radiological Engineering. Inventing the Future.” http://www.mragheb.com , University of Illinois, 2010.