NUCLEAR ENGINEERING INTERNATIONAL

Feature

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A four reactor power plant

B&W's baby

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Babcock & Wilcox, maker of the nuclear reactors in US Navy submarines, believes that thinking small may be the best way to approach nuclear new build. Will Dalrymple reports

In contrast to the most popular new-build reactors such as the Westinghouse AP1000 or Areva EPR, Babcock & Wilcox's newest reactor, unveiled in June, is all about the small. B&W boasts that when the mPower goes on the market in 2012, each 125MWe reactor would be made in a factory, cost about half a billion dollars firm fixed price, and could be built and installed, in multiples of two or four reactors, in only three years.

At the heart of Babcock & Wilcox's proposed mPower nuclear plant concept is a cylindrical vessel, 23m by 4.5m (75ft by 15ft), that holds all the components of the nuclear steam supply system: from bottom to top, fuel rods, control rod assemblies, primary loop pumps, steam generator and pressuriser. The reactor generates 400MWt, or 125MWe with air-cooled condensers, for a cycle efficiency of 31%. A water-based heat sink such as a river or the sea, provides greater cycle efficiency, increasing power generation capacity to 136MWe. The main data are shown in the table.

A key difference between mPower and conventional PWRs comes as the water rises into the steam generator. In conventional PWRs, primary coolant flows through tubes and secondary coolant fills the void space surrounding them. In the mPower, the primary coolant flows outside the tube bundles, and secondary coolant is in the tubes. The mPower steam generator is effectively inside-out compared with normal practice. "This...is fundamental to how the thing is put together," says Chris Mowry, president and CEO of Babcock & Wilcox modular energy, which is developing the mPower reactor. He says that this design comes from B&W's heritage providing nuclear steam supply systems for US Navy submarines and the first nuclear powered ships. "The integration of the reactor and steam generator really went back that far. It has developed over the past 20 years working with the US government; this programme didn't just rise like a phoenix from nothing last year."

Below the steam generator, but above the reactor, are the control rod drives, with one control rod per fuel assembly. Mowry says the concept is similar to that used in submarines. He adds, "Our reactivity control method does not use any soluble boron. That's turned out to be a bit of a headache in PWRs because of operational issues and complexity."

The fact that the nuclear steam supply system is in a single vessel makes the safety case simpler. There are no primary loop penetrations, apart from a 2in-diameter clean-up valve at the top of the reactor. "The advantage of having no primary system penetrations is that there is no large piping, so no possibility of a large break accident in the primary loop," Mowry says, which means no need for emergency injection pumps to douse the core with water. Most importantly the height of the unit means that a design-basis accident would not drain the reactor core. "There is still 5m of water on top of the core after a transient," Mowry says.

The designers propose a simple system for removing decay heat from the reactor in an emergency situation using gravity-fed external water tanks.

Pragmatic and practical

Instead of rotating the fuel for up to three burns, as in conventional PWRs, the fuel has a single five-year burn, at the end of which the entire core is replaced in one load.

The refuelling operation would be expected to last about a week. A gantry crane lifts off the top half of the vessel and places it on a stand. It then lifts off the internal pump ring, to set down on a second stand, exposing the reactor core for change-out. A nearby spent fuel pond would store 12 cores worth of fuel, enough for a 60-year lifetime. Mowry adds that forward-thinking customers might consider buying an extra steam generator that could be swapped in during the refuelling outage. Then the previous steam generator could be inspected once the reactor is back on line, at leisure and off the critical path, saving time and money.

The reactor core and reactor containment is designed to sit entirely underground.

Mowry explains that the company's design is based on pragmatic and practical plans to achieve its goal of generating power in 10 years. First, the company is aiming to cut out all of the new technology in the reactor to improve its chances of sailing through the regulatory approval process. Hence no unforced convection, which, although being designed into GE's ESBWR, has not been licensed in the USA. The lack of primary piping simplifies the LOCA safety case, as does the reactor's height, which prevents the core from being uncovered in design-basis accidents, so removing the need for some safety system engineering. He adds that this conservatism of design differentiates mPower from '95%' of other small reactors currently proposed, almost all of which have fourth-generation technology in them. He says. Babcock and Wilcox plans to submit a design certification application in 2012, with hopes of receiving certification in 2015.

Marketing

Another thing that differentiates mPower from some other recently proposed small reactors, such as NuScale and Hyperion, is that the company has the manufacturing capabilities to turn the concept into reality, Mowry says. The company seems to have designed the reactor to suit its manufacturing strengths. The vessel size, approximately the size of a conventional PWR steam generator, is the largest unit that can go by rail from the factory.

The reactor is small enough for the reactor vessel head and bottom to be forged in North America. Most of the rest of the unit would be assembled in factories, rather than in the field. "We want to provide an NSSS as an integrated module, manufactured in a factory, and rail-shipped assembled. The construction process is more akin to a combined-cycle gas turbine plant than to a standard large commercial nuclear reactor," Mowry says, estimating that an mPower plant would take about three years to build.

B&W plans to invert the normal nuclear construction process when building an mPower unit. "In a large plant you have to build the reactor first on the site, and then build the rest of the power plant around that. Our approach is to build the power plant first and then at the end bring in integrated modules that you lower in place and bolt together to piping. You can build the modules in parallel with field activity to shorten construction times." B&W plans for a lead customer to submit a combined operating licence application in 2013, with hopes for approval in 2015-2016, during the end stages of which construction could begin. According to this schedule, first startup could be around 2018-2019.

B&W's biggest customer, the US military, continues to rely on the company for nuclear submarine reactors. Mowry says that US military technology protecting its nuclear reactors will not be transferred to the mPower reactor project, partly because they are secret, and partly because the performance requirements of civil nuclear reactors are much less stringent than in submarines. Still, the company is in a privileged position to use the same manufacturing lines, and the same brainpower, that build the Navy-spec NSSS. "The factories are already there. Our additional investment for the initial stages of market adoption are minimal," Mowry says, adding that if the project takes off, the company would be prepared to invest in new manufacturing lines.

Supply-side advantages allow the company to offer a 500MWe power station comprising four mPower reactors plus turbine and generator for a cost of 'within 10%' of $3500/kW, which Mowry says is a recent estimate of costs for two 1350MWe ABWRs at the South Texas project. B&W has not yet begun to sell the station. But when it does, unlike other nuclear vendors, who have to hedge risks involved in highly complicated construction projects with incentive-based contracts, B&W's manufacturing controls will be able to sell the unit as an 'essentially' firm-price contract.

Several mPower reactors can be combined in a single power station to provide 2, 4, 8 or more multiples of 125MWe power. NSSS units could be twinned or possibly quadrupled to drive a single large turbogenerator set for larger stations, or a single reactor could connect to a single turbogenset. As a result, the mPower reactor-based power station is being marketed in three different size ranges: 500-750MWe; 125-250MWe, e.g. for municipalities or replacement of old 200-300MW coal-burning stations now considered too polluting to continue in operation; and 1000MWe or above. An attraction for larger plants is that the capacity can be added in steps rather than all at once, allowing stepwise capital investment, with the first module producing early revenue before the others are completed. The cost of competing large reactors is so high – perhaps $10 billion for two units – that it exceeds many utilities' market capitalisation, Mowry says. "You are betting the company on one station, and utilities do not want to do that."

A letter of intent has been received from TVA to begin the process of evaluating a potential lead plant site, possibly Clinch River. It is to be hoped that mPower fares better than a previous innovative reactor proposed for that site, the USA's first commercial fast breeder, on which construction started but was never completed.

According to Mowry, Exelon Corp. is considering mPower for early site activities at its Victoria County site in Texas. "There are other large US utilities looking at it seriously," he says.

B&W has set up an industry council that consults on aspects of the mPower design. The committee currently includes potential customers Dominion Energy of the USA, Bruce Power of Canada and Vattenfall of Sweden.

The company has also aimed its sights overseas, for developing and developed markets. "For the developing world, the poster child is really the UAE, which is actively pursuing nuclear power generation. In Abu Dhabi, the model going forward is to use the certification of the reactor in the country of origin," Mowry says. In other words, the company will not start marketing mPower until 2015. On the other hand, developed countries such as the UK would want to licence the reactor themselves, so US certification is not necessary.

"We would want to have our design relatively mature, so I don't think it is meaningful to say that we would pursue licensing the new plant in the UK before 2012," Mowry says.

mPower - main data

Reactor type: Integral PWR
Power: ~125MWe, ~400MWt
Reactor coolant: <14MPa (2000psia), ~600K (620F)core outlet
Steam conditions: <7MPa (1000psia), superheated
Reactor vessel diameter: ~3.6m (12ft)
Height: ~22m (70ft)
Fuel assemblies Sixty-nine 17x17, uranium dioxide
Height: ~half of standard fuel assembly
Fuel assembly pitch: 21.5cm
Active core height: ~200cm
Core diameter (flat to flat): ~200cm
Fuel inventory: <20t
Average specific power: ~20kW/kgU
Core average fuel burnup: <40GWd/tU
Target fuel cycle length: ~5 years
Maximum enrichment: <5%
Reactivity control: Control rods
Other features: No soluble boron, air cooled condenser,spent fuel stored in containment for 60 year design life

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