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The Next Generation of Nuclear Power

EPM's Systems and Safety Analysis Division has worked tirelessly for decades to aid the continued safety and reliability of the American and International nuclear fleet. As the group continues to support the aging of these plants from the original Nuclear Renaissance, other projects have begun to support the certification of new reactor designs. Two projects currently undertaken by the EPM SSA group involve supporting the certification of NuScale's widely publicized Small Modular Reactor (SMR) design and the Korea Electrical Power Corporation (KEPCO) APR1400 design. Though these two designs involve very different technologies, EPM is able to apply our extensive experience interacting with the regulatory bodies of the nuclear industry, and engineering expertise to both.

KEPCO E&C APR1400 Design Certification and UAE Build

The KEPCO APR1400 is an advanced pressurized water nuclear reactor, developed as a Generation III reactor, with improved thermal efficiency, increased power and capacity. The new design also incorporates a complete digital instrumentation and control system, utilizing fiber optic cable, an upgrade not utilized widely in US plants in favor of the older analog systems[1]. The reactor design utilizes a two loop system, each with a dedicated steam generator and two reactor coolant pumps to direct coolant through the core. A single pressurizer is located on the hot leg of one loop. A new Integrated Head Assembly (IHA), which includes the Control Element Drive Mechanism (CEDM), Air Handling Unit (AHU), cable tray systems and other Containment Vessel systems, has been design which reduces refueling and outage time as well as the component storage area at the head of the vessel[2].

Passive safety features, seismic load and economic cost effectiveness were the focus of this design. The Core Damage Frequency (CDF), and important measure of the plants inherent safety which U.S. regulations require to be less than 10^{-5} per Reactor Year, has been reduced to 2.25×10^{-6}. Due in part to the IHA design described above, seismic load above the core vessel has been reduced, and the design implements the revised requirements for plant seismic profiles following the Fukushima disaster of 2011. The basemat, containment, and auxiliary building structures of the APR1400 are intended to be Seismic Category I structures with ability to withstand the maximum potential earthquake stresses[3]. With all nuclear reactors, the expected capital costs are quite large, though the APR1400 design attempts to mitigate these issue by providing a high plant availability (90% or higher), longer

[1] APR1400. KEPCO E&C Business. http://www.kepco-enc.com/English/sub.asp?Mcode=B010030.
[2] Overview of the APR1400 Design. IAEA INPRO Conference. November 2013. http://www.iaea.org/INPRO/7th_Dialogue_Forum/Korea_Overview_of_APR1400Design_Rev01.pdf.
[3] Jung-Bum, et al. Seismic Design Parameters of the APR1400 DC. Korean Nuclear Society Spring Meeting, May 2012. http://www.kns.org/kns_files/kns/file/2%C0%E5%C1%A4%B9%FC.pdf.

refueling interval (18 Months), modular construction and a comparable thermal efficiency (35.1%). The final estimate cost for the 1450 MWe plant is $2300/kW, bringing the expected cost of new plants to ~3.3 billion USD[4].

Several of these reactors are already in operation in South Korea, and have been supported by EPM's Engineering and Software team, and a new unit is under construction at the Barakah site in the United Arab Emirates. To facilitate foreign export of the KEPCO design, the APR1400 must be approved through the Design Certification (DC) process laid out by the US Nuclear Regulatory Commission (USNRC)[5], this process began on March 05, 2015. EPM has supported KEPCO through this process, aiding specifically in the development of the Multiple Spurious Operation (MSO) addendum to the Fire Safe Shutdown Analysis (FSSA), though engineering support has been made available for future NRC inquiries, analyses and revisions. Being a part of this project has gained EPM insight into the future of nuclear builds, certification processes and the regulatory bodies of other countries. The development of an astute regulatory body for the United Arab Emirates, the Federal Authority for Nuclear Regulation (FANR), shows the Middle East is prepared to embrace nuclear power as a sustainable, greener alternative to the disputed oil reserves of the country.

NuScale Small Modular Reactor (SMR) Design Certification

The NuScale design is one of several SMR designs that have applied for a design certification with the NRC. The design basis for a NuScale SMR is similar to that of a PWR; it uses a 17x17 LWR fuel assembly, the water that is within the vessel, and the heat is transferred to a secondary loop so that the cooling water in the primary loop does not leave the vessel (thus minimizing the potential for radiation to escape the vessel). The major variance from a PWR is that the NuScale design uses natural circulation within the reactor vessel to allow cooling water to circulate through the reactor core. As water is heated by the core, it rises to the top of the vessel. At the top, it is cooled and sinks back to the bottom to the reactor core. By utilizing the natural phenomena of convection and gravity, no Reactor Coolant Pumps are required to circulate water through the reactor.[6]

The use of natural circulation is an essential passive safety feature of the NuScale SMR. By not requiring primary pumps to provide cooling to the reactor core, natural circulation allows a reactor to shutdown naturally during a potential event, such as the one experienced at Fukushima Dai-ichi in March of 2011. In doing this, the plant is designed to be able to shutdown with less dependency on other equipment, inherently increasing the safety of the plant if external factors were to impact its operation.

[4] Advanced Nuclear Power Reactors. World Nuclear Association, April 2015. http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Advanced-Nuclear-Power-Reactors/.
[5] Nuclear Power in the United Arab Emirates. World Nuclear Association, March 2015. http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Arab-Emirates/.
[6] How NuScale Technology Works, May 2015. http://www.nuscalepower.com/overviewofnuscalestechnology.aspx

Each NuScale module (as well as other SMR designs) could stand alone as a single unit. However, the benefit of SMR technology is that multiple units can be placed in a single plant, increasing the electrical output of the plant, reducing the footprint, and decreasing the economic capital of the build. This makes the new SMR design economically competitive, dependent on their acceptance by the public and the opportunity for large scale, serial production. In fact, the design certification submitted to the NRC uses a 12 unit plant design, which is more units at a single site than any other reactor design currently operating in the United States.[7]

EPM has been working with NuScale to support their FSSA development, this includes assisting and reviewing the plant's selection of the Safe Shutdown Equipment list, recommended separation of the plant, Fire Hazards Analysis (FHA) and MSO analysis. The project is essential to the support of the design certification of the NuScale plant as they continue their application process with the NRC in hopes of becoming a certified advanced reactor design. The primary challenge facing SMRs today is licensing, the NRC must recognize the validity and safety of these new designs and modify the regulatory frameworks accordingly. With EPM's assistance, NuScale is hoping to facilitate these changes and bring SMR's not only to the United States, but to countries around the world looking to develop a nuclear program and decrease their oil and natural gas dependence.

[7] Pre-Application Documents for the NuScale Design, April 2015.
http://www.nrc.gov/reactors/advanced/nuscale/documents.html