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Surry, USA

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35th Year of Publication

Instrumentation & Control

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33 years of Journal issues are available online through the Journal website **www.NuclearPlantJournal**.com (search box on the right-top) for a nominal fee of $25 per issue. Contact: Anu Agnihotri, email: anu@goinfo.com.

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Utilities:	2,904

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Industry Innovations

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Journal Services

On The Cover

In 2014, Dominion teamed up with AREVA to proactively address IGSCC at Surry units 1 and 2, putting together a plan to refurbish two RCPs at Unit 1 and three RCPs at Unit 2. See page 48 for more. The cover picture is Dominion's Surry Nuclear Power Plant.

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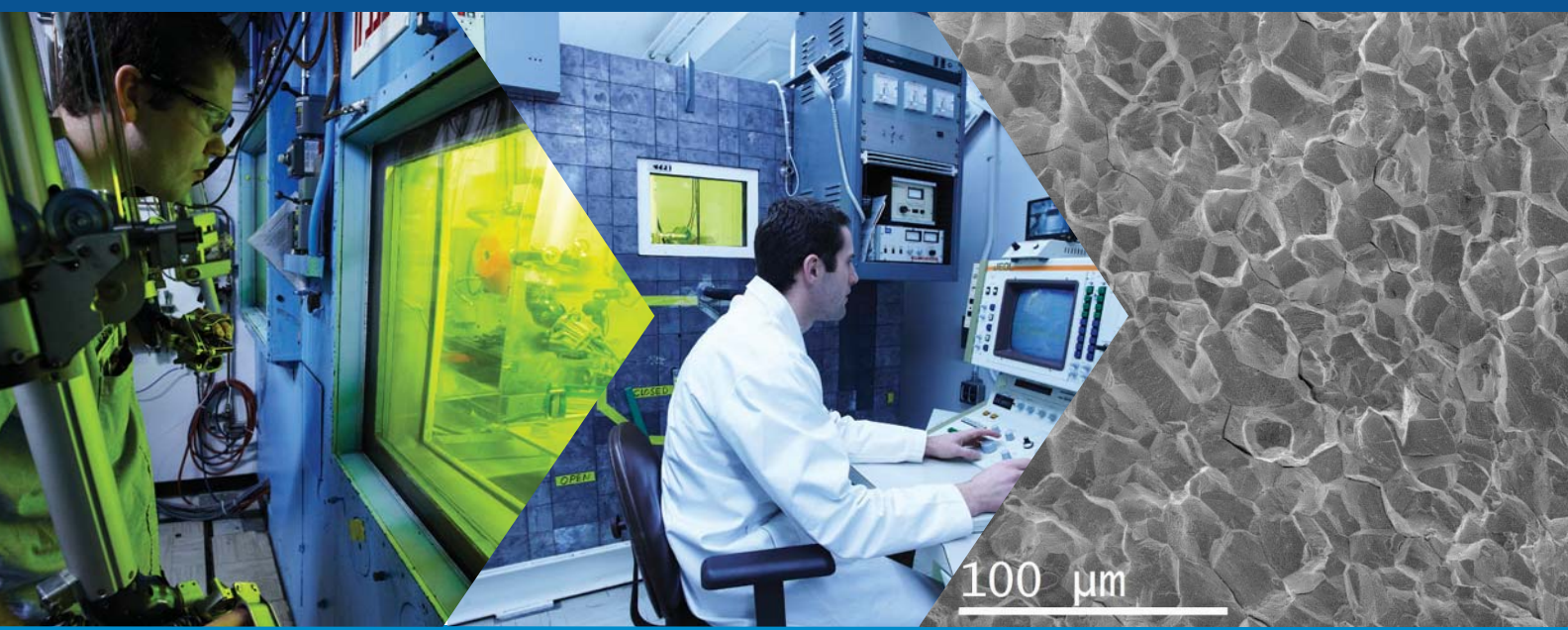

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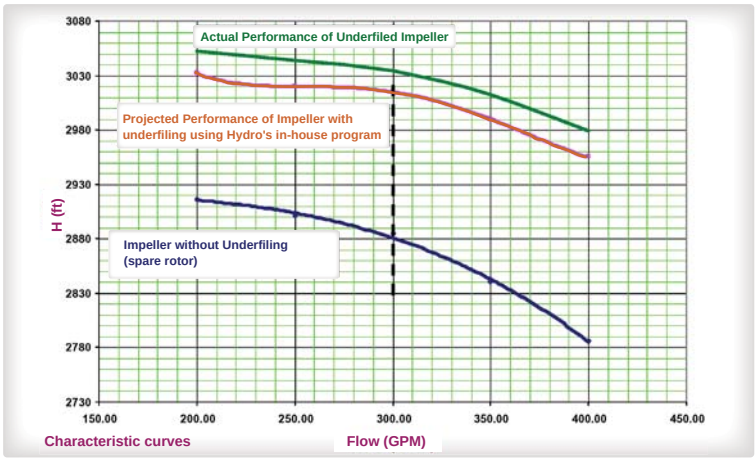
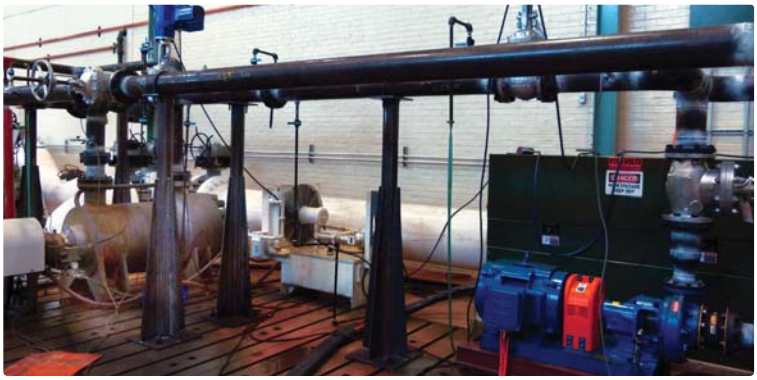
Endurance Testing for Service Water Pump

A 48-hour endurance test was performed for a nuclear power plant when they contacted HydroAire about conducting a research study. The power plant engineers wanted to collect data to assess how long the 1750 HP motor driving their essential service water pump could continue to operate with a deteriorating lower bearing. To learn the complete details of this research study, contact Faisal Salman at **info@nuclearpumptesting.com** or call **312-399-9913.**



Performance Testing for Safety Injection Pump

Within a critical 2-week timeframe, HydroAire helped a nuclear power plant avoid de-rating by reverse engineering and rebuilding a Goulds 8-stagesafety injection pump rotor. The rotor, rebuilt with engineered upgrades, was performance tested. Performance was proven at 1288lbs. pressure – 8lbs. better than the original rotor and 88lbs. above the minimum allowance. Read the full case study at **hydroinc.com/performancetest.**



Air Void Testing for Safety-Related Feed Pump

Hydro's engineers performed 40 air void tests in 10 days for a nuclear power company that had to prove their Pacific 4" BFIDS auxiliary feed pump would perform its safety-related service if an air void greater than 2% passed through the pump. Hydro's Test Lab provided a live video feed of real-time performance data for the NRC to monitor. Read the full case study at **hydroinc.com/voidtest.**

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New Energy

United Kingdom

The Department of Business, Energy & Industrial Strategy (BEIS) has today confirmed that the nuclear regulators have been asked to begin the Generic Design Assessment (GDA) for the UK HPR1000 nuclear technology. This marks a first step in the robust and thorough process to seek permission to build a nuclear power station at Bradwell in Essex.

China General Nuclear Power Corporation (CGN) and **EDF** had submitted a joint application through their joint venture company GNS (General Nuclear System Ltd) to BEIS in October 2016 to begin the GDA process for a UK version of the HPR1000 nuclear technology. The reference plant for the design is CGN's Fangchenggang Plant Unit 3 in China which is under construction and on schedule.

This is a key step in the development of proposals from CGN and EDF for a new nuclear power station at Bradwell in Essex. The UK's nuclear regulators, the Office for Nuclear Regulation and the Environment Agency are among the most rigorous, independent nuclear regulators in the world. All nuclear operators in the UK must work within this strict regulatory framework, and all reactor designs satisfy the safety, security and environmental requirements of the Generic Design Assessment process.

The proposed Bradwell project is in an early pre-planning stage which will involve years of investigative works and public consultations before detailed proposals are produced allowing a planning application to be made. A UK version of HPR1000 reactor is intended to be built at Bradwell following GDA approval.

CGN and EDF have been working together for more than 30 years on nuclear development and construction in China. They have formed an industrial partnership in the UK to build Hinkley Point C nuclear power station in Somerset and to develop Sizewell C in Suffolk and Bradwell B in Essex.

The GDA process will take a number of years to complete. There are a number of different consents and permissions to be achieved before a nuclear power station can be constructed. In addition to GDA process, other requirements include development consent, site licensing and environmental permits.

Contact: Marjorie Barnes, EDF Energy, telephone: 01728 653378, email: Marjorie.barnes@edf-energy.com.

Watts Bar Unit 2

The nation's first new nuclear generation in 20 years has officially entered commercial operation after the **Tennessee Valley Authority's** Watts Bar Unit 2 successfully completed an extensive series of power ascension tests and reliably operated at full power.

The $4.7 billion capital construction project was completed on budget. The unit now moves to working asset status.

Watts Bar Unit 2 has already provided consumers across the Valley with more than 500 million kilowatt-hours of carbon-free energy during testing. It now joins six other operating TVA nuclear units to supply more than one third of the region's generating capacity, and meeting the electric needs of more than 4.5 million homes.

Watts Bar, Sequoyah and Browns Ferry nuclear stations have also contributed to reducing TVA's carbon emissions by 30 percent since 2005, a reduction that will rise to 60 percent by 2020.

Contact: Jim Hopson, TVA, telephone: (865) 632-6000, email: tvainfo@tva.gov.

China

Installation of the fourth and final reactor coolant pump at the Sanmen 2, an AP1000 was completed in January, 2017, China National Nuclear Corporation (CNNC) announced. Meanwhile, the boron injection tank has been installed at the second demonstration Hualong One unit being constructed at the Fuqing plant.

Each AP1000 includes four main reactor coolant pumps - each almost seven metres tall (22.97 feet) and 1.5 metres (3.28 feet) wide and weighing some 91 tonnes - which circulate reactor coolant through the core, loop piping and steam generators.

Westinghouse is currently constructing four AP1000 units in China, two each at Sanmen in Zhejiang province and Haiyang in Shandong. US manufacturer Curtiss-Wright was awarded a contract by Westinghouse to produce 16 reactor coolant pumps for the units in 2007.

Sanmen unit 1, construction of which began in April 2009, is expected to be the first AP1000 to begin operating. First concrete for Sanmen 2 was poured in December 2009. All four Chinese AP1000s are scheduled to be in operation by the end of this year.

The boron injection tank was also installed at Fuqing 6 - the second Hualong One unit under construction at the site in China's Fujian province.

The boron injection tank - weighing almost 20 tonnes - will contain a boric acid solution that can be injected into the reactor in the event of a severe accident to shut down the chain reaction in case the control rods are not capable of being inserted into the core.

China's State Council gave final approval for construction of Fuqing units 5 and 6 in April 2016. The pouring of first concrete for the reactor basemats for Fuqing 5 and 6 - marking the official start of construction of the units - took place in May and December 2015, respectively. Fuqing 5 and 6 are scheduled to be completed in 2019 and 2020.

Construction of two Hualong units is also under way at China General Nuclear's Fangchenggang plant in Guangxi province.

*Source: **World Nuclear News**, website: http://world-nuclear-news.org*

Clinch River

The Tennessee Valley Authority (TVA) has welcomed the acceptance for regulatory review of its early site permit application for the Clinch River site in Tennessee as a milestone towards the potential use of small modular reactors (SMRs) in its operating fleet.

The docketing of the application by the US Nuclear Regulatory Commission (NRC) on December 30, 2016 was formally reported in the US Federal Register on January 12, 2017. The NRC may now begin its technical review of the application, during which NRC staff will

(Continued on page 14 Column 3)

Utility, Industry & Corporation

Utility

License Extension

Entergy's Grand Gulf Nuclear Station has been approved to provide customers safe, secure and reliable energy for two additional decades, thanks to an operating license extension granted by the U.S. Nuclear Regulatory Commission. A ceremony was held in the NRC's corporate offices in Rockville, Maryland.

From left: Patrick Williams (Grand Gulf director of engineering), Nathan Brown (Cooperative Energy Senior VP/Chief Operating Officer) and Tom Coutu (Grand Gulf director of regulatory and performance improvement) join William M. Dean (NRC Director, Office of Nuclear Reactor Regulation) for the Grand Gulf license renewal signing ceremony.

Photo courtesy of Entergy.

The extension comes after five years of intensive reviews and assessments to ensure the plant's safety, operational capability and environmental impact will meet or exceed standards into the future. The license extension validates that Grand Gulf is poised to continue operations through the year 2044, two additional decades past the original licensing date.

Grand Gulf, the only nuclear plant to produce power in Mississippi, generates just under 20 percent of the state's electricity while emitting no greenhouse gases. By operating virtually emission-free, the plant actually prevents the annual release of 11,038 short tons of sulfur dioxide, 8,105 tons of nitrogen oxide and 7 million metric tons of carbon dioxide.

Contact: Jami Cameron, Entergy, telephone: (601) 437-6393, email: jcamer1@entergy.com.

Crew Performance Observations

China National Nuclear Power Co., Ltd (CNNP) currently has 15 power reactors in commercial operation, with 12,162 MWe of generating capacity online. The company has 9 nuclear units under construction and several more planned. CNNP established a working group in 2016 in order to continuously improve the operator skills of their nuclear fleet.

From January 2014 to March 2016, the member companies of China National Nuclear Power Co., Ltd (CNNP) have accepted Pre-start up Peer Reviews (PSURs) conducted by the **World Association of Nuclear Operators** (WANO).

The specific units reviewed are Fangjiashan Units 1&2 of CNNP Nuclear Power Operations Management Co., Ltd., Fuqing Units 1, 2&3 of Fujian Fuqing Nuclear Power Co., Ltd., and Hainan Units 1&2 of Hainan Nuclear Power Co., Ltd.

As a part of WANO PSURs in the operating area, Crew Performance Observations (CPOs) aim to help units to detect and correct possible Areas for Improvement (AFIs) before initial criticality. By observing the crew teams under simulated scenarios, especially observing their responses to transients and complex conditions, WANO helps to assess crew readiness and the effectiveness of related training.

In order to continuously improve the operator skills of each member company, the CNNP established a working group in 2016 to improve operator skills. The working group consists of experts from member companies of CNNP and RINPO (Research Institute of Nuclear Power Operation, a technical supporting institute for CNNP). CNNP and its member companies provide financial support to this group.

Contact: Katie Bailey, WANO, telephone: 44 (0) 20 7495 9241, email: Katie.bailey@wano.org.

Industry

Nuclear Waste Storage

Senator Lamar Alexander's (R-Tennessee) statement in response to DOE putting in a request for information for an interim nuclear waste storage site.

"The Department of Energy's decision to proceed with interim storage for used nuclear fuel, which was recommended four years ago by the Blue Ribbon Commission on America's Nuclear Future, is an important step forward. I hope Congress will take the next step and pass bipartisan legislation I have introduced to create temporary and permanent facilities to store and dispose

(Continued on page 12)

Industry...

(*Continued from page 11)*

of our used nuclear fuel, and authorize a new pilot program for nuclear waste storage that Sen. Feinstein and I included in the Energy and Water Development Appropriations bill again this year. We need to move on all tracks at the same time to solve the nuclear waste stalemate to help ensure that carbon-free nuclear power has a strong future in this country. Yucca Mountain can and should be part of the solution, but we have more than enough waste to fill Yucca Mountain to its legal capacity."

Contact: Louie Brogdon, **Office of U.S. Sen. Lamar Alexander***, telephone: (202) 224.8848, email: louie_brogdon@alexander.senate.gov.*

Reactive Metal Waste Streams

Veolia Nuclear Solutions announced the successful demonstration of their GeoMelt® In-Container Vitrification (ICV)™ process for treatment of reactive metals. Veolia, under contract with Idaho National Laboratory (owned by the U.S. Department of Energy and managed by Battelle Energy Alliance, LLC) demonstrated safe conversion of sodium metal to a non-reactive vitrified oxide form.

The demonstration, supported by glass formulation and crucible testing, consisted of a series of ICV melts that processed elemental sodium into a stable non-reactive form. The work was carried out at Veolia Nuclear Solutions GeoMelt Test Site in Richland, Washington.

Battelle Energy Alliance, LLC is evaluating the GeoMelt® technology as a means to safely and reliably convert radioactive reactive metal residues that contaminate components from sodium cooled reactors into waste forms that comply with existing disposition pathways. Reactive metal wastes at Idaho National Laboratory (INL) require treatment to comply with disposal restrictions. GeoMelt®, which is an alternative to other potential treatment approaches, provides a robust approach that chemically converts the reactive metals to an inert oxide while also immobilizing radionuclides in a vitrified waste form with durability equal to or better than vitrified nuclear fuel reprocessing wastes (very robust and inert waste forms).

Contact: Claire Billon-Galland, Veolia Nuclear Solutions, email: claire.billon-galland@veolia.com.

Nuclear Excellence Award

Every two years, **World Association of Nuclear Reactors** (WANO) presents Nuclear Excellence Awards to individuals who have made a significant contribution to the nuclear industry or to the successful operation of nuclear power plants operated by WANO members.

An independent selection committee, including representatives from all WANO regional centres, selects the award recipients from a list of nominees.

Any individual whose work contributes to or supports the successful operation of nuclear power plants operated by any WANO member is eligible for an award. This could include contributions to any part of the infrastructure that supports the nuclear power enterprise. It could also include contributions made through WANO.

The individuals will receive their awards at WANO's Biennial General Meeting in Gyeongju, South Korea in October 2017.

Visit the WANO member website (members.wano.org) for more information or to download the nomination form. Deadline for nominations is March 31, 2017.

Contact: Katie Bailey, WANO, telephone: 44 (0) 20 7495 9241, email: Katie.bailey@wano.org.

Corporation

Collaboration Agreement

Amec Foster Wheeler announced that it has signed a collaboration agreement with Tecnatom SA, under which the two companies will work together to create an enhanced offering for customers in the nuclear industry.

The agreement covers equipment and materials qualification, non-destructive testing, remote handling, and training services.

Contact: Steve Brauner, Amec Foster Wheeler, telephone: 44 1565 684462, email: stephen.brauner@amecfw.com.

Metallic Nuclear Fuel

Lightbridge Corporation, a U.S. nuclear fuel development company, and **AREVA NP**, a leader in nuclear fuel, components and reactor services, have agreed upon key terms for the creation of a new joint venture to develop, manufacture and commercialize fuel assemblies based on Lightbridge's innovative metallic nuclear fuel technology designed to significantly improve the economics, efficiency and safety of existing and new nuclear power facilities.

The two companies signed a term sheet on October 31, 2016, outlining key agreements for a U.S.-based joint venture to be equally owned by each company and covers fuel assemblies for most types of light water reactors, including pressurized water reactors (PWRs), boiling water reactors (BWRs), small modular reactors (SMRs) and research reactors. The two companies expect to formalize the joint venture in the coming months.

Contact: Curtis Roberts, AREVA, telephone: (202) 374-8766, email: Curtis.roberts@areva.com.

Acquisition

BWX Technologies, Inc. announced that its subsidiary BWXT Canada Ltd. has completed its acquisition of the GE Hitachi Nuclear Energy Canada Inc. joint venture, which has been re-named BWXT Nuclear Energy Canada Inc. (BWXT NEC).

A supplier of fuel, fuel handling systems, tooling delivery systems and replacement components for CANDU® reactors, BWXT NEC will now operate as a subsidiary of BWXT Canada and will maintain its current locations and management team, including President Mark Ward, who will lead the subsidiary.

Contact: Natalie Cutler, BWXT Technologies, telephone: (519) 620-5288, email: nacutler@bwxt.com.

Advanced Reactor Development

GE Hitachi Nuclear Energy (GEH) and Southern Nuclear have agreed to collaborate in studying the development and licensing of advanced reactors including GEH's PRISM sodium-cooled fast reactor design.

In a Memorandum of Understanding signed by GEH and Southern Nuclear Development, a subsidiary of Southern Nuclear Operating Company, the companies have also agreed to work together toward participating in future U.S. Department of Energy advanced reactor licensing projects.

PRISM is a sodium-cooled, high energy neutron (fast) reactor design which uses a series of proven, safe and mature technologies developed both in the U.S. and abroad. The PRISM design has benefited from the operating experience of EBR-II, an integral fast reactor prototype which was developed by Argonne National Laboratory and operated for more than 30 years in Idaho Falls, Idaho.

GEH believes that no U.S. fast spectrum reactor technology has more testing, design or operational experience than PRISM. On this basis, PRISM seems well positioned to continue the licensing process and to generally provide a critical regulatory path for licensing of other advanced reactor technology in the U.S.

According to an analysis performed by GEH, which assumes a quantity of 178,000 metric tons of nuclear material contained in used fuel stocks worldwide, by using PRISM technology on a commercialized basis, all the world's used fuel could eventually be consumed while at the same time providing enough clean, carbon-free energy to power all global households, (estimated at approximately 1.6 billion living units) for as long as 200 years, based on a per household consumption of 3,400 kWh/year.

Contact: Jon Allen, GE Hitachi Nuclear Energy, telephone: (910) 819-2581, email: jonathan.allen1@ge.com.

Simulator Modernization

L3 MAPPS announced that it has received an order from Instituto Nacional de Electricidad y Energías Limpias (INEEL) to support the modernization of the Laguna Verde (Mexico) full scope simulator for Comisión Federal de Electricidad (CFE). In the first phase of the project, INEEL will develop a classroom simulator using L3 MAPPS' Orchid® simulation environment equipped with interactive virtual panels and emergency diesel generator local panels. The overall modernization project will be executed in multiple phases, with the first phase set to complete in the second half of 2017.

L3 MAPPS will deploy its Orchid simulation suite, to be utilized for all phases of the modernization project, and will train INEEL's simulation personnel. During the first phase, INEEL will replatform the existing plant simulation from a third-party platform to Orchid and will develop the virtual panels with L3 MAPPS' on-site and remote support. INEEL will also develop new emergency diesel generator models using Orchid Modeling Environment.

Laguna Verde Simulator.
Photo courtesy of L3 MAPPS.

At the end of the first phase, Laguna Verde trainees will interact with the simulation via L3 MAPPS-provided Orchid Touch Interface bays for an accurate representation of the control room environment using touchscreen monitors with 1080p full HD resolution. For added realism, INEEL will also include simulated control room sounds using Orchid Sound System. Laguna Verde's instructors will control and monitor all aspects of the simulation with Orchid Instructor Station. The emergency diesel generators will be interfaced to the simulation with a Beckhoff I/O system driven by Orchid Input Output.

Contact: Sean Bradley, L3 MAPPS, telephone: (514) 787-4953.

Water Jet Peening

Mitsubishi Nuclear Energy Systems, Inc. (MNES) has completed the first U.S. water jet peening (WJP) project to prevent stress corrosion cracking of reactor vessel nozzles (RVNs) and bottom mounted nozzles. All planned nozzles were successfully peened within the customer's standards and quality specifications. MNES achieved excellent radiological safety with personnel dose less than 50% of established target and 100% industrial safety with no first aids, near misses or OSHA recordables. AZZ|WSI, Inc. supported MNES as the primary implementation lead on the project. The project team was also supported by Mitsubishi Heavy Industries, Ltd. (MHI), Structural Integrity Associates, and Anatec LMT. The WJP process is a MHI low-risk Alloy 600 stress corrosion cracking mitigation solution with 15 years of field-proven experience conducted at 21 plants in Japan. This project further demonstrates a successful transfer of Japanese nuclear technology to meet U.S. nuclear industry

(Continued on page 14)

Corporation...

(*Continued from page 13)*

needs. "The success of this technology transfer paves the way for MNES to introduce other MHI-proven technologies to the U.S. nuclear fleet," remarked Yoshinobu Shibata, MNES President & CEO.

MNES is currently conducting an intensive lessons learned review of the Wolf Creek water jet peening project. The lessons learned will be used to enhance the efficiency and effectiveness of the next MNES WJP process scheduled at Ameren Missouri Callaway Energy Center in fall 2017.

Contact: Rhonda Bishop, MNES, telephone: (704) 945-2643, email: Rhonda._bishop@mnes-us.com.

SMR Design Certification Application (DCA)

In a major step toward the deployment of the next generation of advanced nuclear technology, **NuScale Power** asked the U.S. Nuclear Regulatory Commission (NRC) on December 31st, 2016 to approve the company's small modular reactor (SMR) commercial power plant design. This is the first-ever SMR DCA to be submitted to the NRC and marks a significant milestone for NuScale and the power generation industry. NuScale SMR's will supply affordable, clean, reliable power in scalable plants whose facility output can be incrementally increased depending on demand. Its significant operational flexibility is also complementary to other zero-carbon sources like wind and solar. Once approved, global demand for NuScale plants will create thousands of jobs during manufacturing, construction and operation, and reestablish U.S. global leadership in nuclear technology, paving the way for U.S. NRC approval and subsequent deployment of other advanced nuclear technologies.

NuScale's application consisted of nearly 12,000 pages of technical information. The NRC is expected to take the next two months to determine if any additional information is required prior to commencing their review. Thereafter, the NRC has targeted completing the certification process within 40 months.

The application delivery was commemorated January 12th, 2017 at NRC headquarters, in the Washington suburbs, by NuScale Chief Executive Officer John Hopkins, Co-founder and Chief Technology Officer Dr. Jose Reyes, Chief Nuclear Officer Dale Atkinson, and Vice President Regulatory Affairs Tom Bergman, hand delivering DVD's containing the application.

The first commercial 12-module NuScale power plant is planned to be built on the site of the Idaho National Laboratory. It will be owned by the Utah Associated Municipal Power Systems (UAMPS) and run by an experienced nuclear operator, Energy Northwest.

Contact: James Mellott, NuScale Power, telephone: (503) 715-2233, email: jmellott@nuscalepower.com.

Memorandum of Understanding

Westinghouse Electric Company and Korea Hydro & Nuclear Power Co. Ltd. signed a memorandum of understanding (MOU) to form a technological exchange committee to promote a discussion and exchange of engineering capabilities between both organizations. The bilateral MOU will fully engage the partners' capabilities in nuclear engineering and services through periodic meetings, technological exchanges and business developments.

The MOU will leverage both partners' strengths, including Westinghouse's position in the PWR market and CE fleet operation, and KHNP's strong resources and technology presence. The partners expect to find areas of collaboration in engineering and technology development while enforcing safety, resolving current technical issues, promoting technical improvements and expanding business markets.

Contact: Westinghouse Public and Media Relations, telephone: (412) 374-4744, email: westinghousepublicrelations@westinghouse.com. ■

New Energy...

(*Continued from page 10)*

address site safety and environmental protection issues, as well as plans for coping with emergencies, independent of the review of a specific nuclear plant design. It will also prepare an environmental impact statement and hold a public hearing.

An early site permit, or ESP, certifies that a site is suitable for the construction of a nuclear power plant from the point of view of site safety, environmental impact and emergency planning, but does not specify the choice of technology. The permit is valid for ten to 20 years, renewable for an additional ten to 20 years.

*Source: **World Nuclear News**, website: http://world-nuclear-news.org*

VC Summer

The first steam generator has been lifted into place at the VC Summer nuclear power plant under construction in South Carolina. It is the first such component to be installed at a Westinghouse AP1000 plant in the USA.

The 1.5 million pound (680 tonne) steam generator was lifted into place at Summer unit 2 by one of the world's largest cranes. The unit requires two of the components, which have a diameter of about 6 metres (19.68 feet) and are more than 24 metres (78.74 feet) long. Steam generators transfer heat from the reactor to convert water into steam.

The steam generator was supplied by Doosan of Korea and shipped via the Port of Charleston, completing its journey by rail on a carriage specially designed to transport heavy, oversized loads.

South Carolina Electric & Gas (SCE&G) and co-owner Santee Cooper are building two AP1000s at Summer. Westinghouse is the contractor for the project, and Fluor is the construction manager. Construction began on both units in 2013, with unit 2 expected to start up in 2019 and unit 3 in 2020. A single pressurized water reactor unit is already in operation at the site.

*Source: **World Nuclear News**, website: http://world-nuclear-news.org* ■

New Products, Services & Contracts

New Products

Fuel Product

Global Nuclear Fuel-Americas announced enhancements to its GNF2 fuel product that are aimed at further improving reliability.

The newest version of the product, known as GNF2.02 was launched using GNF's latest process for design iteration including rapid prototyping and testing. Improvements to the Defender™ PLUS debris filter significantly improve the chance of stopping debris before it ever reaches the fuel bundle.

"An improved debris filter means that GNF2.02 will offer our customers even better fuel reliability which translates to lower operating costs," said Amir Vexler, CEO of Global Nuclear Fuel–Americas. "The use of 3D printing to prototype fuel filter designs enabled us to reduce the typical design cycle without sacrificing quality or design rigor. Rapid prototyping will enable us to continue to innovate quickly to meet our customers' needs."

GNF2.02 is available to customers now for shipping in a pre-channeled configuration.

Contact: Jon Allen, Global Nuclear Fuel, telephone: (910) 819-2581, email: jonathan.allen1@ge.com.

Services

CNL

Canadian Nuclear Laboratories (CNL), Canada's nuclear science and technology laboratory, dedicated to developing peaceful and innovative applications of nuclear technology through its expertise in physics, metallurgy, chemistry, biology, and engineering. CNL addresses global issues across the nuclear lifecycle – reactors and fuels, waste management, nuclear safeguards. With over 60 years of experience, CNL is experienced in applied research and development in nuclear material testing and analysis for the commercial utility industry.

Contact: Bill Mangan, CNL, email: William.mangan@cnl.ca.

Contracts

Enhanced Motor Operation Systems

AREVA NP, teaming with Siemens, was awarded a contract for the design, manufacturing, testing, delivery and commissioning of two SINAMICS Perfect Harmony variable frequency drives (VFDs) for PSEG's Hope Creek Nuclear Generating Station in Salem County, N.J. VFDs manage the frequency and voltage of electric motor recirculating pumps in a nuclear energy facility.

VFDs can provide a variety of benefits to nuclear energy facilities. VFDs can be used to reduce the plant's house load, to improve plant control and to allow for flexible plant operations, which responsively modify a nuclear reactor's electricity generation to meet grid demands. The increased ability to vary the speed of motors and pumps can help the facility better manage various processes, including its intake of cooling water to meet the Environmental Protection Agency's requirements of Rule 316(b) of the Clean Water Act.

Contact: Denise Woernle, AREVA, telephone: (434) 832-3848, email: denise.woernle@areva.com.

Refueling Equipment

AREVA NP signed a multimillion-dollar agreement with the Tennessee Valley Authority (TVA) to provide fleet-wide refuel equipment upgrades. Under this contract, AREVA NP will upgrade existing refueling platforms, manipulator cranes, fuel transfer systems and used fuel bridge components. This modern equipment will help operators increase efficiency, strengthen performance and reduce time when receiving, moving and storing nuclear fuel.

AREVA NP will complete this work at Sequoyah Units 1 and 2, Watts Bar Unit 1 and Browns Ferry Units 1, 2 and 3, representing three pressurized water reactors and three boiling water reactors.

Contact: Denise Woernle, AREVA, telephone: (434) 832-3848, email: denise.woernle@areva.com.

(Continued on page 16)

Contracts...

(*Continued from page 15*)

Dismantle Reactors

GE Hitachi Nuclear Energy (GEH) has been awarded a three-year contract by OKG AB to support the dismantling of two reactors at the Oskarshamn Nuclear Power Plant near Oskarshamn, Sweden.

The contract covers the segmentation of reactor pressure vessel internals for Oskarshamn Units 1 and 2. The work, which will include dismantling, cutting and packing the reactor internals for final disposal, will begin in January 2017 and continue through 2019.

Oskarshamn Unit 1 is a boiling water reactor (BWR) that began operations in 1972 and is scheduled to cease operating in 2017. Unit 2, a BWR that began operating in 1974, closed in 2015.

Contact: Jon Allen, GE Hitachi Nuclear Energy, telephone: (910) 819-2581, email: jonathan.allen1@ge.com.

CASTOR® casks

GNS Gesellschaft für Nuklear-Service mbH and Synatom, a subsidiary of the Belgian ENGIE Electrabel, have signed a contract for the development, licensing, and manufacturing of 30 transport and storage casks of the type CASTOR® geo24B and CASTOR® geo21B. From 2021, the casks, which will be manufactured at the GNS facility in Muelheim/Ruhr, will be delivered to the Belgian nuclear power stations, Doel and Tihange. The contract also includes the option for further casks to serve the future demand for storage casks until 2030.

The CASTOR® geo series is based on the existing CASTOR® family of modular cask systems for spent fuel transport and storage, featuring different cask dimensions and basket designs to adapt to the different installations. Based on well-proven components and state-of-the-art processes, this system easily meets the individual requirements of customers worldwide for storage and transport of both PWR- and BWR-fuel assemblies. Owing to different lengths and diameters of the cask cavity CASTOR® geo24B is able to accommodate 24 fuel assemblies, CASTOR® geo21B 21 fuel assemblies.

Contact: Michael Kobl, GNS Gesellschaft für Nuklear-Service mbH, telephone: 49 201/109-1444, email: Michael.koebl@gns.de.

Simulator Upgrade

L3 MAPPS been awarded a contract by United Kingdom-based EDF Energy Nuclear Generation Limited to perform upgrade work on the operator training simulator for the Dungeness B Nuclear Power Station. The two-phase project will start immediately and is expected to be completed in the fourth quarter of 2019.

In the first phase, L3 MAPPS will replatform the legacy simulator from SGI/UNIX® computers to new PC/Windows®-based computers running L3's industry-leading Orchid simulation environment. L3 MAPPS will provide operating crew debrief capabilities with its powerful Orchid Multimedia Manager audiovisual system. Orchid Multimedia Manager is fully synchronized with Orchid Instructor Station and the simulated plant, allowing convenient replay and playback of training scenarios. L3 MAPPS will also provide a classroom environment where the instructor will be able to connect Orchid Instructor Station running on a tablet PC to any of the students' simulations. Additionally, the students will be able to interact with the simulation using virtual panels displayed on three large touchscreens that are enabled with L3 MAPPS' Orchid Touch Interface technology.

Contact: Sean Bradley, L3 MAPPS, telephone: (514) 787-4953.

CANDU Pre-Project

SNC-Lavalin announced that it has been awarded a pre-project contract from Argentina's Nucleoeléctrica Argentina SA for the CANDU nuclear new build project at the Atucha site in the district of Zàrate, about 100 kilometres from Buenos Aires. If this project materializes, it would be the first CANDU new build since Cernavoda Unit 2 came on line in 2007.

The six-month contract will allow SNC-Lavalin to engage with suppliers for long-lead equipment, conduct preliminary design work, deliver safety analysis, offer licensing support and provide technical assistance from Canada.

This announcement comes in the wake of Canadian Prime Minister Justin Trudeau's visit to Argentina where he met with President Mauricio Macri. The two leaders discussed mutual collaboration between the two countries, among other things, as Argentina's economy expands and energy demand increases.

Argentina already owns and operates a CANDU reactor at Embalse, about 650 km northwest of Buenos Aires. Construction of this reactor began in 1976 and it went into commercial operation in 1984. As well as supplying electricity, Embalse is also used to produce Cobalt-60, a radioisotope used in medical and industrial applications. SNC-Lavalin is currently engaged in the life extension of the Embalse reactor.

Contact: Katherine Ward, SNC-Lavalin, email: Katherine.Ward@snclavalin.com.

Control Room Habitability

Nuklearna Elektrarna Krsko (NEK), Slovania, has awarded **Tecnatom** a contract for the performance of control room habitability testing at Krsko nuclear power plant, in Slovenia.

The objective of this new contract is to ensure that in the event of an emergency situation, the control room would be isolated from any outside filtrations, allowing the operators to continue their work inside.

The work will begin with a visual inspection and a detailed analysis to identify the control room ventilation systems and tracer gas injection points. For the performance of this project, Tecnatom will specify a procedure based on the ASTM E 741-00 standard; "Standard Test Methods for Determining Air Change Rates in a Single Zone by Means of a Tracer Gas Dilution".

Within the framework of this contract, Tecnatom will receive support from the local company Q-Techna, with which they have already collaborated in previous projects in Slovenia.

Contact: Manuel Fernandez Ordonez, Tecnatom, telephone: 34 916598600/8619, email: mfordonez@tecnatom.es. ■

New Documents

EPRI

1. *Moisture Management of Electric Motors: Prevention, Detection, and Restoration Guidance*. Product ID: 30020080496. Published December, 2016.

Electric motors are subjected to moisture frequently and water occasionally. The cause of moisture or water intrusion is often preventable, with the exceptions of system failures or natural disasters. This report focuses on preventing, detecting, and restoring electric motors exposed to moisture at power plants.

2. *Program on Technology Innovation: Innovative Nondestructive Evaluation (NDE) Materials Characterization*. Product ID: 3002007775. Published December, 2016.

For nuclear power plants, one key to reliable long-term operation is managing the aging and degradation of primary system metals and nonmetals. This management can be performed through inspections, testing, demonstrations of new technologies, and effective mitigation, repair, or replacement strategies. Advanced inspection and test methods capable of early and more complete characterization of flaws, changes in materials, chemistry, and structure at the micro scale can provide the desired technical information, resulting in a better aging management program.

This report documents an ongoing effort to assess the feasibility, performance, and limitations of NDE materials characterization technologies and other innovative technologies to bring new inspection methods into utilities' toolboxes and improve existing solutions. The study includes two tasks. The first task is to investigate and exploit a novel noncollinear ultrasonic characterization technique and several electromagnetic NDE techniques for measurement of materials properties and detection of subtle microstructural changes caused by aging in various materials. The second task is to investigate four innovative NDE technologies to inspect metals and nonmetals—air-coupled ultrasonic testing, frequency-steerable transducers for bulk wave inspection, terahertz radiation, and ultrasonic camera. The preliminary test results show that the evaluated and developed NDE materials characterization and innovative NDE technologies are promising for several applications. However, further development and modification are needed to successfully adapt them for industry applications.

3. *Single-Side Ultrasonic Examinations for Stainless Steel Piping - Summary of Recent Results*. Product ID: 3002007780. Published December, 2016.

The nature of examinations in power plant piping often requires ultrasonic evaluation from only one side because of geometric constraints and the presence of integral piping supports. The effectiveness of techniques that permit the single-side evaluation of these welded joints has long been in question. This report describes a study to assess the effectiveness of current ultrasonic single-side inspection of austenitic piping, applying specific techniques. Flaws of concern in this study include far-side flaws, oriented both circumferentially and axially, originating at the internal surface of the pipe.

4. *Post-Tensioned Containments: Feasibility Study of Nondestructive Evaluation Inspections in Ungrouted Tendons*. Product ID: 3002007778. Published December, 2016.

This project investigated potential nondestructive evaluation (NDE) methods of post-tensioned tendons. Corrosion or other damage might cause a wire to break and fail to carry any load. Our research identified four methods with potential value for assessing the condition of individual wires in a tendon—electrical time domain reflectometry, electrical resistivity, ultrasonic guided waves, and impact wave testing. The experimental testing focused on impact wave testing. The other three methods are briefly summarized.

The experiments evaluated impact wave testing on 60-ft-long (18-m-long), seven-wire, 12.7-mm-diameter strands with various states of induced damage. An as-received strand was first tested for baseline data without imparting any damage. Subsequently, the strand was cut in incremental steps until a 100% cut was made, simulating a broken strand. An impact was made at one end of the strand, and a sensor was used to detect the mechanical energy at the opposite end. Results showed that a fully broken strand could be detected by a loss of signal. Further studies are needed to determine if the technique will work under field conditions with the strand under tension and in a greased bundle. The method shows promise for greased tendons, but grouted tendons will present a challenge due to the solid bonding conditions between wires.

5. *BWRVIP-304: BWR Vessel and Internals Project, Boiling Water Reactor Crack Mitigation Monitoring Results with Noble Metal Treatment*. Product ID: 3002009291. Published December, 2016.

This report provides a compilation of the results of industry efforts to monitor the effectiveness of the application of noble metals and hydrogen injection to mitigate intergranular stress corrosion cracking (IGSCC) in Boiling Water Reactors (BWRs). Data presented include both experimental laboratory trials conducted as the Noble Metal Chemical Application (NMCA) and On-Line NobleChemTM (OLNC) technologies were being developed, and operational results from several BWR stations. Results from laboratory trials and plant operational data were collected from publications, industry meetings and conferences, and industry surveys. The data collected provide evidence that injected noble metal particles deposit on reactor internal surfaces and piping. The water film ECP on the targeted surfaces is well below the threshold of -230 mV(SHE) at which IGSCC is mitigated when hydrogen injection rates are maintained.

The above EPRI documents may be ordered by contacting the Order Center at (800) 313-3774, Option 2, or email at orders@epri.com. ■

Meeting & Training Calendar

1. **Waste Management Symposia** 2017, March 5-9 2017, Phoenix, Arizona. Contact: Jaclyn Russell, WM Symposia, telephone: (480) 557-0263, email: Jaclyn@wmarizona.org.

2. **Canadian Nuclear Society** (CNS) CANDU Reactor Technology & Safety Course, March 27-29, 2017, Courtyard by Marriot Downtown Toronto, Toronto, Canada. Contact: CNS, telephone: (416) 977-7620, email: cns_office@cns-snc.ca.

3. 19th Annual Electric Power Conference, April 10-13, 2017, McCormick Place West, Chicago, Illinois. Contact: Jill Dean, **Electric Power**, telephone: (713) 343-1880.

4. 2017 **International Congress on Advances in Nuclear Power Plants** (ICAPP), April 24-28, 2017, Fukui and Kyoto, Japan. Contact: ICAPP, email: icapp2017@convention.co.jp, website: http://icapp2017.org

5. World Nuclear Fuel Cycle, April 25-27, 2017, Delta Toronto, Toronto, Ontario, Canada. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

6. Used Fuel Management Conference, May 2-4, 2017, Savannah International Trade and Convention Center, Savannah, Georgia. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

7. Nuclear Utility Procurement Training Course, May 9-12, 2017, **EPRI** Charlotte Office, Charlotte, North Carolina. Contact: Lynette Evans, EPRI, website: www.epri.com

8. International Conference on Nuclear Engineering (ICONE), May 14-18, 2017, Shanghai Convention Center, Shanghai, China. Contact: **American Society of Mechanical Engineers**, telephone: (800) 843-2763, email: customercare@asme.org.

9. 64th Annual Industry Conference and Supplier Expo: Nuclear Energy Assembly, May 22-24, 2017, Westin Kierland, Scottsdale, Arizona Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

10. 37th Annual **Canadian Nuclear Society** Conference, June 3-7, 2017, Sheraton on the Falls Hotel, Niagara Falls, Ontario, Canada. Contact: Canadian Nuclear Society, telephone: (416) 977-7620, email: cns_office@cns-snc.ca.

11. International Conference on Topical Issues in Nuclear Installation Safety: Safety Demonstration of Advanced Water Cooled Nuclear Power Plants, June 6-9, 2017, Vienna, Austria. Contact: Martina Neuhold, **International Atomic Energy Agency**, telephone: 43 1 2600 21314, email: m.neuhold@iaea.org.

12. Emergency Preparedness Training Course, June 11-13, 2017, Westin Savannah, Savannah, Georgia. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

13. 2017 **American Nuclear Society** Annual Meeting, June 11-15, 2017, Hyatt Regency, San Francisco, California. Contact: Sue Gorney, ANS, email: registrar@ans.org.

14. 10th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies, June 11-15, 2017, Hyatt Regency, San Francisco, California. Contact: **American Nuclear Society**, email: registrar@ans.org, website: http://npic-hmit2017.org

15. Emergency Preparedness Forum, June 14-15, 2017, Westin Savannah, Savannah, Georgia. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

16. National Nuclear Security Conference, June 20-22, 2017, Hilton Austin, Austin, Texas. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

17. International Conference on Fast Reactors and Related Fuel Cycles: Next Generation Nuclear Systems for Sustainable Development (FR17), June 26-29, 2017, Yekaterinburg, Russian Federation. Contact: Martina Neuhold, **International Atomic Energy Agency**, telephone: 43 1 2600 21314, email: m.neuhold@iaea.org.

18. **American Society of Mechanical Engineers** Power & Energy Conference & Exhibition, June 26-30, 2017, Charlotte Convention Center, Charlotte, North Carolina. Contact: American Society of Mechanical Engineers, telephone: (800) 843-2763, email: customercare@asme.org.

19. **UniTech** R^3 Nuclear Workshop, June 28-30, 2017, Indianapolis, Indiana. Contact: Gregg Johnstone, UniTech Services Group, telephone: (413) 543-6911 x 146, email: gjohnstone@UniTechUS.com.

20. Nuclear Fuel Supply Forum, July 18, 2017, The W Hotel, Washington, D.C.. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org.

21. U.S. Women in Nuclear Conference, July 23-26, 2017, Hilton San Francisco, San Francisco, California. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8091, email: registrar@nei.org. ■

Research & Development

EPRI

Susceptibility Analysis

While digital instrumentation and control (I&C) systems at nuclear plants offer significant advantages over their analog predecessors, their use creates the potential for new and sometimes subtle misbehaviors and failures. Using EPRI guidance, plant owners can avoid issues before they occur by conducting a susceptibility analysis as soon as they have a conceptual design of the proposed digital I&C system.

Why Plants Are Going Digital

To maintain safety and operability goals, nuclear utilities need to ensure their I&C systems are highly dependable. When it becomes necessary to replace obsolete equipment, utilities typically apply digital technology for better fault tolerance, automated diagnostics that increase availability, and expanded communication capabilities. New nuclear plants will be "all digital"; they will use more extensive and highly integrated I&C systems than existing plants.

How EPRI Guidance Can Help

The guidance found in Methods for Assuring Safety and Dependability When Applying Digital Instrumentation and Control Systems (EPRI 3002005326) was tested on five plant modification projects and found to be helpful and practical. The approach systematically identifies potential I&C vulnerabilities that could lead to significant malfunctions of controlled components and systems, including common-cause failures and discusses in detail methods to protect against them.

Using the guidance, plant owners and operators can qualitatively assess the risks associated with a proposed I&C implementation, considering both preventive measures that reduce the likelihood of failures, and plant systems and features that mitigate the effects of component failures and misbehaviors. The safety-significance-based graded approach can help users focus on overall plant safety, including potentially risk-significant scenarios that might not be considered in traditional safety analyses.

For each of four basic sources of I&C failures—random hardware failures, environmental disturbances, operational and maintenance errors, and design defects—the susceptibility analysis assesses the preventive and limiting measures in place to help manage risk. Coping analysis then is recommended where appropriate to determine whether the results are acceptable, should a failure occur, and to provide additional assurance of protection. The guidance recommends using existing thermal-hydraulic analyses of postulated accidents and transients performed for safety and risk assessments where possible to help manage costs.

"This report will help users address technical concerns regarding digital system failure susceptibilities and their potential effects on the plant," said Ray Torok, EPRI technical executive. "The preventive and limiting measures described, if implemented with appropriate consideration of potential application-specific issues and mitigation capability, should provide a basis for assuring sufficient protection. However, users should not assume that the lists of recommended measures are exhaustive or that they comprehensively address all situations."

The EPRI guidance includes examples to help design engineers grasp the concepts and learn how to apply these methods into their digital I&C modification packages. Plus, Torok said, industry workshops and training likely will be needed over the next few years to familiarize users with this approach and to identify improvement opportunities.

BWR Inspection Guidance

Intergranular stress corrosion cracking of boiling water reactor (BWR) internals began to emerge as a significant issue for nuclear plants in the mid-1980s. In response, EPRI developed and implemented a multi-year program, the BWR Vessel and Internals Program (BWRVIP), to manage the degradation of reactor internals and help assure continuing safe operation of BWRs. From 1994 to 2000, a number of inspection and evaluation (I&E) guidelines were developed by the BWRVIP.

Today, the fleet-wide implementation of BWRVIP guidelines continues to generate a substantial amount of information for BWR reactor vessel internals. This field inspection data can be used to better assess the degradation susceptibility of various BWR internals components.

The first optimized BWR internals guideline, for core spray internal piping and spargers (BWRVIP-18 Revision 2), has now been approved by the Nuclear Regulatory Commission and is being implemented by BWRVIP member utilities. Through the optimization process, inspections are now being focused on locations with the greatest propensity for cracking, based on evaluation of extensive field inspection data. At the same time, inspections of locations found not to have significant susceptibility to cracking have been reduced or eliminated.

Providing Guidance to Respond to Industry Challenges

As plants have worked to maintain and enhance AC system reliability, EPRI has provided various reports to support the industry in meeting these objectives. Topics addressed in these reports include post-trip voltage prediction (EPRI 1018535), transformer maintenance (EPRI 1002913), and open-phase phenomenon (EPRI 1025772).

Off-site power systems are connected to nuclear power plants through nuclear plant switchyards. EPRI developed the Nuclear Switchyard Maintenance and Application Guide (EPRI 1026664) to assist power plant personnel in their understanding of switchyard configurations, typical equipment, and the requirements associated with maintaining the equipment.

Changes in regulations have given power plant personnel more responsibility for their large power transformers and switchyard equipment than they had in the past. EPRI's nuclear sector responded by forming the Transformer and Switchyard Users Group providing a forum for power plant personnel to exchange operating experience and lessons learned related to maintaining a reliable connection to an AC power source.

The primary equipment required to distribute and receive power is the

(Continued on page 20)

Research & Development...

(*Continued from page 19)*

transformer. To assist member utilities in educating plant personnel responsible for monitoring and maintaining large power transformers, EPRI created a detailed reference source that covers virtually everything related to transformers. The "Copper Book" (EPRI 3002005902) is the product of a cross-sector initiative involving EPRI's power delivery, nuclear, and generation sectors.

In 2014, EPRI developed a method to detect an open-phase condition on transformers that are susceptible to this anomaly (EPRI 3002004432). Now commercialized, this method is being used in many nuclear power plants to detect the presence of an open conductor in the off-site power system. The development of this method is particularly significant because an open-phase condition can go undetected by conventional power plant relaying.

EPRI began work on the Nuclear Off-site Power Reliability (NOPR) roadmap in 2015. Another cross-sector project, the NOPR roadmap is based on detailed operational experience reviews of LOOP (loss of power) and partial LOOP events over the last 10 years. The project is focused on building a strategy to improve offsite power reliability with a more collaborative approach, bringing together stakeholders and focusing EPRI research on implementing solutions.

Buried Pipe Management

Research and development to enable the preservation and management of buried pipes has been part of EPRI's portfolio since 2008.

In 2009, the U.S. nuclear industry came together to develop the Buried Piping Integrity Initiative (approved by the Nuclear Strategic Issues Advisory Committee) and the associated guidance document "Guideline for the Management of Underground Piping and Tank Integrity" (NEI 09-14). This initiative established the expectations for an asset management plan that would provide reasonable assurance of the structural and leakage integrity of the systems, structures, and components (SSC) that are identified as scope within the initiative.

EPRI has supported the initiative and has focused on research to enable the development and implementation of assessment, management, and mitigation strategies for buried piping and tanks to enable the utilities to develop asset management plans.

The primary focus of EPRI's research and support has been non-destructive examination assessment techniques, programmatic support (e.g., risk ranking of SSCs), and mitigation strategies such as options for pipe replacement and pipe repair (i.e., using cured in place pipe liners), and cathodic protection (CP). With the initial effort to develop buried pipe management programs, assess the current condition of buried pipes, and develop asset management plans complete as of December 2014, many plants are turning their focus toward implementation of the long-term asset management plans, including the role of CP.

CP System Understanding and Guidance

CP is a focus area for EPRI as part of the overall strategy to develop tools that members can use to maintain buried pipe assets, as CP can be a cost effective way to manage the potential for corrosion, thus avoiding future costs for asset repair, refurbishment, and replacement. This becomes important for nuclear power plants that are operating into their extended period of operation. In understanding the state of the industry in this area, it was determined that some nuclear power plants were designed with a CP system for buried pipe whereas at other stations the design did not include a CP system. The usage, condition, and maintenance of existing systems varied. "To enable members to efficiently and effectively apply cathodic protection to buried assets, EPRI has been focused on developing improved guidance on the design, operation, maintenance, and assessment of cathodic protection systems; including training and education for both system responsible engineers and engineering management," said Dylan Cimock, EPRI lead for Cathodic Protection and Coatings.

To bridge existing gaps in knowledge, EPRI has developed improved guidance on the application, operation, and maintenance of CP systems. Reports such as Cathodic Protection Application and Maintenance Guide (3002000596) and Recommendations for Managing an Effective Cathodic Protection System (3002002949) have been instrumental in helping nuclear plants with CP maintenance and application. In 2012, EPRI also formed a CP users group to bring together utility personnel who could share successes, issues, and overall experiences with CP, as well as provide a forum for members to interact with technology suppliers capable of assisting in systematic CP assessments and upgrades as applicable.

Recently, one nuclear power plant that had originally been constructed without CP utilized the EPRI report, Evaluation for Installing or Upgrading Cathodic Protection Systems (3002005067), to systematically assess their current and future need to install a CP system with consideration given to operating to 60 to 80 years. Utilizing the process outlined in the report, the utility ultimately reached the conclusion that, while an adequate margin currently exists for buried SSCs, additional activities, such as periodic excavations and installation of corrosion rate monitoring probes, are recommended to determine future CP requirements.

The Future of CP

Over the past seven years, EPRI has observed that CP is being implemented as a mitigating strategy in the long-term asset management of buried SSCs, including an increase in the number of CP system upgrades, refurbishments, and new installations.

EPRI continues to conduct research that will foster greater understanding of CP systems, including effective maintenance strategies. In 2015 and 2016, EPRI conducted a project titled State of the Fleet Assessment of Cathodic Protection Systems (3002007627) intended to capture utility best practices related to CP, identify common issues and deficiencies, and provide a source of benchmarking for common operation, maintenance, and system management practices.

The above are excerpts from EPRI's The Nuclear Connection Winter 2017 newsletter. These were reprinted with the permission from EPRI. Contact Renita Crawford at (704) 595-2888 or rcrawford@epri.com with any comments or questions.

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(Continued on page 43)

Cost Efficient Methods

By Allen Hsu, Doosan HF Controls.

Allen Hsu

Allen Hsu is the President and CEO of Doosan HF Controls. He designed and tested industrial distributed control system for power plants, water treatment facilities, petrochemical process plants, and cement plants. Hsu designed and programmed software on controllers, peripheral devices, and host computers. He designed and programmed software for digital and analog control interpreters and networking software. Hsu is familiar with HFC control system architecture and network communication scheme, Intel microprocessors used in HFC, the Assembler language programming, and the Microsoft Visual studio environment. He has experience to handle the multiple overall projects execution of Nuclear Power Plant Control System in HFC.

Hsu has a BS Electrical Engineering from N.C.T.U. in Taiwan and a MS Computer Science from the University of Texas at Dallas.

Responses to questions by Newal Agnihotri, Editor of Nuclear Plant Journal.

1. *What customized analog and digital instruments and systems have been provided by HF Controls for safety-related applications?*

Doosan HF Controls has a complete line of digital and analog cards for safety and non-safety platforms. The analog cards come in TC, RTD, and 4-20ma input cards, the output cards come in 4-20ma, 0-10v or 1-5v. The digital cards have inputs and output relay options. Doosan HF Controls has supplied control systems for many projects, just to name a few: feedwater controls, radwaste controls, diesel generator controls, seismic tripping systems and many others.

2. *Describe the safety-related and non-safety-related legacy equipment, which HF Controls can help replace meeting the form, fit and function requirements?*

Doosan HF Controls has a product line for safety related systems, HFC-6000 platform. This platform come in either 19 or 21 inch racks. These racks can easily replace existing racks for convenient upgrades. The non-safety platform ECS-1200 is panel mounted and can fit in any existing cabinets as well.

3. *Does HF Controls have all the requisite experts; design engineers, installation engineers and startup engineers available in-house?*

Doosan HF Controls is a one stop shop, we have hardware and software engineering that design all our Printed Circuit Boards (PCB's) and software for the cards. DHFC has application engineers, who design the actual field application for each individual projects. DHFC has a completely separate V &V engineering group as well as startup engineering group.

4. *How does HF Controls protect the utilities from effects of obsolescence when:*

- *The digital equipment is manufactured by HF Controls?*

Doosan HF Controls has a separate group within R&D that handles obsolescence on our existing platforms. If this group determines that we can't purchase the obsolescence part, then the R&D group determines that the card will have to be redesigned with new components. This has already been done successfully on several occasions converting microprocessors to FPGA design.

- *Cases when the equipment is not manufactured by HF Controls?*

This is determined on a case by case basis. DHFC can usually find compatible components for the intended use. DHFC also has a Commercial Grade Item Dedication (CGID) department that can test the components to verify functionality.

5. *Is HF Controls flexible in customizing its products and services to meet the plant's requirements?*

FPC08 Controller Card.

Since Doosan HF Controls has its own R&D department, we are considered a customize shop and can handle any modification a customer might want. Almost every large project will have at least one item that is custom to that project which will require redesign or a new design.

6. *How does HF Controls handle the safety-related I & C business, when complete guidelines are unavailable from the regulating organization in different countries?*

(Continued on page 22)

Cost Efficient...

(*Continued from page 21)*

Every country with civilian nuclear program has its own governing body that regulates and monitors its own fleet of plants. If they don't have their own guidelines then they will use the US NRC standards.

7. *Does HF Controls have any recommendations to the US NRC in its "Implementation of Integrated Action Plan for the Modernization of the NRC's Digital I&C Regulatory Infrastructure" for safety-related I & C.*

The issue is not implementing hardware and software upgrades to existing site, it's all the regulatory hoops the sites and vendors have to jump through to just implement the changes. Granted, any change would have to be proven safe and secure, but there are easier and more cost efficient methods than how the US NRC is handling these issues today. These types of changes are happening all over the world today and are being completed on time and under budget without the US NRC involvement.

8. *How does HF Controls prevent the, "Common Cause Failure" in its equipment?*

The quick answer to this hard question, is that DHFC has two different safety products that can be used to prevent common cause failure. These two products are microprocessor based Plant Control Systems (PCS's) and FPGA family of PCB's. Both products each have their own set of digital and analog cards and can be used in different channels for example for diversity. DHFC has other methods of achieving diversity that can be used on either platform, if needed.

9. *How does HF Controls ensure the future availability of parts for manufacturing the circuit boards for the US nuclear power plants?*

Doosan HF Controls has a two prong approach to handling the upgrading of parts. All of our major components that have announced retirement of the component, DHFC will do a large last time buy of the component before it become obsolete. This assures DHFC that the PCB's can be produced for a time frame so that new components or new designs can be done. The second method is to revise the PCB and remove the obsolete component with a new design or new component as soon as the old component obsolesces is announced. DHFC has been successful in both approaches.

HFC-6000 Cabinet Assembly.

10. *Does HF Controls assist professional societies such as IEEE and ASME in preparing I & C standard for the nuclear power industry?*

Doosan HF Controls has two professionals who are on working groups within the IEEE. The two individuals are continually working on new and updated standards for the nuclear industry.

Contact: John Stevens, Doosan HF Control's Corp., 1624 W. Crosby Rd. #124, Carrollton, TX. 75006; telephone: (469) 203-1381. ■

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Meeting the Nuclear Promise

By Tony Spear, OTEK Corporation.

Tony Spear

Tony Spear is the Director of Sales and Marketing, OTEK Corporation. His technical experience was honed by his years at IBM Corporation. During his tenure he was awarded an IBM Corporate Outstanding Innovation Award for leading teams responsible for testing and design assurance of several major state-of-the-art storage subsystem products.

After leaving IBM, he founded Foothills Printing Inc, an Arizona corporation, and served as president and general manager. He provided not only the leadership for his business but also consulting services in management, business planning, budgeting, financial management, human resources, marketing planning, IT and major account sales for a growing list of customers.

Mr. Spear holds a Bachelor of Science Degree in Electrical Engineering from Purdue University, a Master of Science Degree in Electrical and Computer Engineering from Stanford University, and a Graduate Certificate in Marketing from the University of California at Berkeley.

Responses to questions by Newal Agnihotri, Editor of Nuclear Plant Journal.

1. *How do OTEK Corporation instruments meet Nuclear Energy Institute's call for, "Nuclear Promise"?*

The nuclear I&C room, with its range of 300 to 800 instruments, represents a tremendous cost-saving opportunity to help plant operators meet *The Nuclear Promise* goal of a 30% cost reduction. Many analog instruments are 40-50 years old and no longer offered by their original equipment manufacturers. Once popular and easy to procure, analogs must now be purchased from specialized refurbishers who charge $10,000 to $25,000 for a fully qualified instrument. Along with their stuck needles and inherent lack of precision, analog meters require frequent calibration: common practice is to recalibrate every instrument at every outage. This is a huge labor expense and a clear savings opportunity.

The OTEK NTM (New Technology Meter) Series is a combination digital meter/bargraph featuring OTEK's patented "self-powered" technology. Recent advancements in low-power LED (Light Emitting Diode) technology allow certain models of the NTM Series to be powered by the same 2-wire input signal that drives the existing analog meters - without the need for external power. The engineering mod to run a new power system in the control panel is a huge investment of money and effort which can now be avoided. There is no need to try to cram more wires behind an already too-crowded panel. The NTM Series is designed to be 100% *Form, Fit and Function* compatible with a wide range of commonly-used analog (as well as many obsolete digital) instruments for plug-and-play compatibility.

A bright, 4-digit LED display provides readings accurate to within 0.05% of full scale. A tricolor digital bar graph provides the visual feedback of the analog needle along with field programmable red, yellow and green set-points.

Cost savings from using NTM Series Instruments are significant. Not only are NTM priced 50-75% less than refurbished, qualified instruments, the NTM Series virtually eliminates the labor required to recalibrate during every outage. Additionally, the NTM series features a common electrical design throughout the product line. Spares inventory can be reduced with common-design, multi-use instruments that can be field-personalized on an as-needed basis.

NTM Series instruments are obsolescence-hardened, designed with multi-sourced, off-the-shelf components, and featuring a calculated MTBF of over 25 years. All NTM Series products are covered by the OTEK's exclusive Lifetime Warranty: any unit that fails under normal operating conditions will be repaired at OTEK's expense for the life of the instrument.

2. *How is OTEK Corporation currently complying with the US NRC requirements and Nuclear Energy Institute guidelines?*

During 2016, OTEK executed a signed 10CFR50 Appendix B Nuclear QA program and has completed the Tier 1 and Tier 2 program implementation procedures under that program. OTEK is in the process of completing all of the specific Tier 3 manufacturing and engineering procedures required to manufacture products for Class 1E safety-related nuclear applications. OTEK expects to complete that activity during 1Q2017.

OTEK will also maintain the QA procedures necessary to build our products to existing commercial grade. Operators who have their own commercial grade dedication organizations will be able to obtain OTEK products as commercial grade if that option better fits their supply chain requirements.

OTEK products have been designed to be used as Critical Digital Assets (CDA's) that are protected under each utility's Cyber Security Plans (CSP) as specified in NEI 08-09 (Revision 6), *Cyber Security Plans for Nuclear Power Reactors*.

3. *How does OTEK Corporation support utilities meet the cyber security plan for its supplied and installed products?*

Designed to be appropriate for use as a CDA within a nuclear power plant, OTEK products adhere to stringent requirements in the following 3 areas: (1) Software Development Process, (2) Hardware and Software Development Environment and (3) Product Cyber Security Features.

(i). Software Development Process:

- Software is developed in accordance with accepted Software Quality Assurance (SQA) standards such as IEEE 730-2014, I*EEE Standard for Software Quality Assurance Processes*. The SQA process exists to evaluate whether the software conforms to product requirements and accepted industry standards, and can be used to measure product quality as well as the effectiveness of processes used to develop the product.
- Any digital product to be used as a CDA must go through a stringent Software Validation and Verification Process (SV&V).The SV&V will verify the reliable performance of all critical device characteristics necessary to perform the required safety function of the device. The SV&V will also contain specific information about the process and product features designed to protect the CDA from cyber attack.

(ii). Hardware and Software Development Environment:

- Hardware and software is developed behind a firewall.
- Regular virus protection scans are performed and documented.
- Source code and compiled code are stored on an "air-gapped" workstation not connected to the Internet. The workstation is backed-up and virus-scanned regularly.
- A "zero-knowledge" off-site backup system where the host of the backup copy has no access to the unencrypted version of the code.
- A cyclic redundancy check (CRC) is added to the executable code stored in the NTM device and is checked during the manufacturing process to verify the code has not been corrupted during installation.
- All critical characteristics of the NTM, as defined in the SV&V report, are verified by OTEK as part of the device final acceptance test and documented by serial number for traceability.

(iii). Product Cyber Security Features:

a. Physical access to the configuration settings of the NTM is only through a serial data port which can be placed either internal to the device, behind the scale plate, or at the rear behind the control panel. (See Figure 1)

b. Logical access to the device functions is password-protected with a user-programmable password.

c. Graphical user interface software to set the password, change configuration or calibrate the NTM is provided by OTEK free-of-charge. (See Figure 2 on page 26).

d. Executable code for the NTM is stored on non-volatile memory. Configuration data is stored in a separate location from the executable code.

e. A watchdog timer function detects a failure of the microprocessor or a failure to receive input signals in a timely fashion.

f. A "signal fail" indication begins immediately after a loss of input signal and broadcasts for 30 to 60 seconds.

Figure 1: OTEK NTM-9 Digital Panel Meter and Bargraph. Note the access to the serial I/O port is behind the faceplate which requires removal of 4 screws in order to access the port. Access only from the rear of the instrument, behind the control panel, is also available.

g. Control relays with both normally open and normally closed contact points are available to accommodate fail-safe interaction with the rest of the external control system.

h. Hardware safety limits for output signals to prevent damage to downstream equipment in the event of a failure or cyber attack.

(Continued on page 26)

Meeting the...

(*Continued from page 25*)

4. *Describe the safety-related and non-safety-related legacy equipment, which OTEK Corporation can help replace meeting the form, fit and function requirements?*

NTM Series instruments can be used to be a Form, Fit and Function replacement for the following legacy products: DB40, Sigma 9200 & 9300 series, Chessell 700, TA Bailey's RY & 775 series, Foxboro 257, and Dixson SA101 along with many others.

5. *How does OTEK Corporation protect the utilities from effects of obsolescence when:*

- *The digital equipment is manufactured by OTEK Corporation?*

OTEK strives to design a replacement product before discontinuing any of our legacy products, particularly those known to be used in nuclear applications. All known existing OTEK legacy products which have been logged by utilities in the Rolls-Royce POMS database have been updated with an OTEK NTM Series replacement product.

- *Cases when the equipment is not manufactured by OTEK Corporation?*

There are literally thousands of obsolete analog instruments, such as the GE180 and DB40 models, in the POMS database that can be replaced with a modern, reliable and obsolescence-hardened OTEK NTM solution. OTEK and Rolls Royce are currently working together to provide, within the POMS database, an OTEK solution for these and similar obsolete instruments.

6. *Is OTEK Corporation flexible in customizing its products and services to meet the plant's requirements?*

Absolutely. All OTEK products for the nuclear industry are custom-built to order and offer many custom features required for safety and compliance with industry standards. OTEK's current best practice is to assign a custom part number for all products to be placed in nuclear service to guarantee absolute traceability and repeatability for the life of the product.

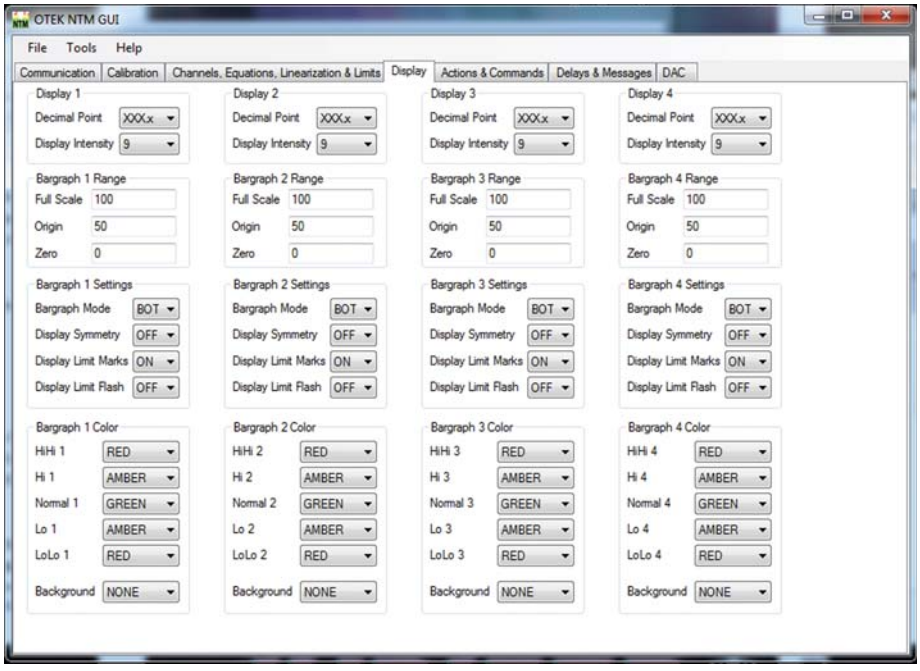


Figure 2: Screen shot from the Free OTEK GUI User Software illustrating the various configuration settings that are available to the user for personalization in the field.

Contact: Tony Spear, Otek Corporation, 4016 E. Tennessee Street, Tucson, AZ 85714; telephone: (520) 748-7900, email: tony@otekcorp.com. ■

Extensive Experience

Ron Legrand, AREVA NP.

Ron Legrand

Ron Legrand serves as AREVA Inc.'s Division Director for instrumentation and control (I&C) modernizations in North America, a position he has held since July 2016. His responsibilities include managing AREVA NP's current I&C portfolio as well as developing new products for the I&C market. Legrand has been with AREVA since 2003.

Previously, Legrand served as the manager of integrated work management at Constellation Energy Group; work control and outage manager at North Atlantic Energy Service Corporation; and director, mid operations support, west regional operations group and pressurized water reactor outage manager at Exelon. Other positions he held include division vice president, operations support group; division vice president, nuclear operations; and plant manager at Duquesne Light Company.

Legrand began his career with Southern Company, holding various positions of responsibilities including operations manager and health physics and radiochemistry manager at Plant Vogtle. He holds a Bachelor of Science degree from the University of South Carolina – Columbia.

Responses to questions by Newal Agnihotri, Editor of Nuclear Plant Journal.

1. *With AREVA NP's extensive experience, what is its recommendation to the U.S. NRC in their "Implementation of Integrated Action Plan for the Modernization of the NRC's Digital I&C Regulatory Infrastructure" for safety-related I&C?*

We fully support the U.S. Nuclear Regulatory Commission's (NRC) effort to modernize the regulatory infrastructure for digital instrumentation and control (I&C), as outlined in the NRC Integrated Action Plan (IAP). Based on our extensive experience in executing digital upgrades worldwide, we believe there are significant benefits associated with the use of digital technology to improve the safety and reliability of the U.S. nuclear fleet.

We are committed to supporting our customers around the globe with the best available digital I&C technology. To ensure our worldwide experience and lessons learned are shared with the industry and to best support the NRC IAP, AREVA NP loaned a full-time executive to the Nuclear Energy Institute (NEI) in the United States. Through 2017, this individual is tasked with working with the NEI Digital I&C Working Group to develop clear technical guidance and consistent regulatory requirements, and to ensure efficient processes are in place, providing high confidence that digital I&C projects can be implemented on time and within budget. This AREVA NP executive has extensive experience in digital I&C systems and serves as the NEI leader for one of the key modernization plan activities contained within the IAP. This hands-on approach enables AREVA NP to share insights with NEI, others in the industry and NRC staff.

2. *How does AREVA NP prevent "Common Cause Failure" in its TELEPERM XS technology?*

The NRC's position on common cause failures (CCFs) in digital systems identifies two principle factors for defense against common mode/common cause failures: quality and diversity.

- Quality: Maintaining high quality increases the reliability of both individual components and complete systems. The NRC staff has reviewed the TELEPERM® XS platform qualification and software development life cycle processes, and determined that TELEPERM® XS has the required quality.
- Diversity: The assessment of diversity is a plant-specific activity that has to be completed by each licensee applying TELEPERM® XS. As part of the review of the TELEPERM® XS platform Topical Report, AREVA NP provided a plant-specific defense-in-depth methodology that the NRC stated was consistent with the staff position and was therefore acceptable for use by licensees in applications.

In addition to protecting against random failures and internal/external events, CCFs must be taken into careful consideration in the design and engineering of safety I&C systems. In the United States, AREVA NP has designed safety I&C systems to address CCF requirements specified by the NRC's requirements.

This process was used successfully for Duke Energy's Oconee Nuclear Station upgrade to its Reactor Protection System (RPS) and Engineered Safeguards Protection System (ESPS) using AREVA NP's TELEPERM® XS. The licensee performed plant-specific diversity (D3) analysis with the assumption that all RPS and ESPS safety functions could become subject to a software CCF. They also used realistic assumptions to perform best-estimate analyses of licensing-basis plant responses, then identified necessary back-up systems as well as manual operator actions necessary for accomplishing the required safety functions. The NRC found this approach acceptable.

(Continued on page 28)

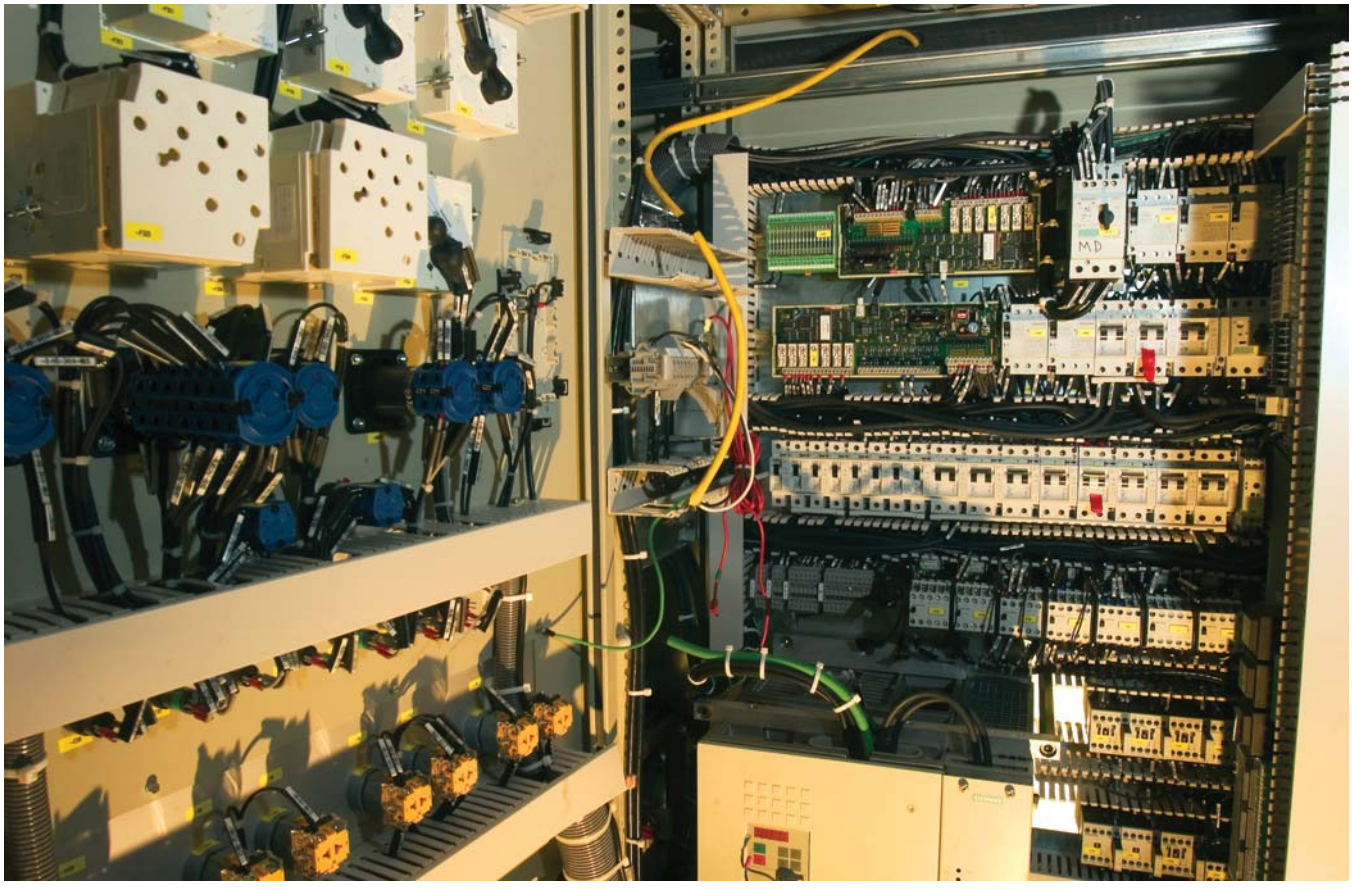
Extensive Experience...

(*Continued from page 27)*

3. What are the main systems controlled by the 20 new cabinets supplied to Electrabel for its Doel unit one and unit two emergency system building?

The 20 cabinets will be subdivided into four polarities (two for each unit). Sixteen cabinets will be located inside the emergency building and four cabinets will be located in the electronic rooms beside the main control room. The following emergency systems will be operated, controlled and monitored by TELEPERM® XS systems:

- Auxiliary feedwater system
- Blowdown system
- Component cooling system
- Chemical and volume control system
- Emergency cooling system
- Emergency feedwater
- Emergency instrument air
- Emergency ventilation
- Feedwater system
- Liquid waste system
- Main steam system
- Demineralized water system
- Boron preparation
- Pool loops
- Pressurizer system
- Primary sampling system
- Reactor coolant system
- Emergency cooling of primary pumps' seals
- Shutdown cooling system
- Secondary floor drainage system
- Safety injection system
- Secondary sampling system
- Emergency shutdown/SCRAM
- Turbine



AREVA NP's TELEPERM® XS integrates extensive self-monitoring features into its system platform.

4. *Has Electrabel used wireless technology as compared to hardwired cables for its systems in the emergency system buildings, within the building and also the connections with the main control room?*

The signal transfer between the emergency building and the main control room was based on ISKAMATC B fiber optic transfer modules, both binary and analog. These will be replaced by AREVA NP's TELEPERM® XS Profibus cables and Ethernet cables using fiber optic cables.

5. *What enhancements have evolved since the installation of safety-related control systems at Duke Energy's Oconee nuclear power plant in 2009?*

Since the beginning, AREVA NP's TELEPERM® XS platform has been continuously developed in order to enhance functionality and application coverage, and improve obsolescence robustness. The current platform, which uses more than 100 different modules, covers virtually all nuclear power plant needs on safety I&C applications. This includes, but is not limited to, reactor protection (trip and engineered safety features actuation systems), reactor control and limitation systems, ex-core neutron flux monitoring systems, feedwater control systems, emergency diesel generator controls and continuous boron measurement. The latest high-performance application of TELEPERM®

XS is the advanced load following control system, enabling a fully automated load following of up to 30 megawatts per minute while maintaining full reactivity control.

6. *What nuclear plant systems, in addition to recirculating water pumps, utilize variable frequency drives?*

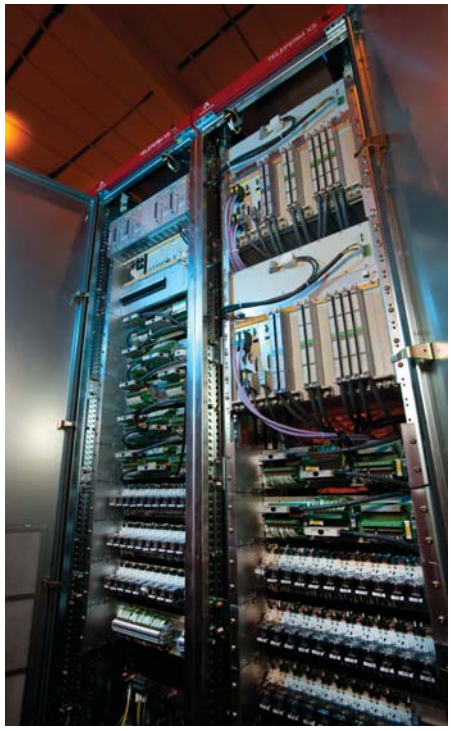
AREVA NP, in partnership with Siemens, is the exclusive channel to the installed base U.S. nuclear market for Siemens variable frequency drives (VFDs). Currently, there are 30 Siemens Perfect Harmony water-cooled VFDs in operation in boiling water reactor recirculating systems in the United States. These VFDs replaced obsolete reactor recirculation pump motor-generator sets and are high-availability, water-cooled VFDs that improve redundancy, minimize single-point vulnerabilities, reduce house load (resulting in payback through increased supply to the grid), enhance flow control, reduce maintenance, increase reliability and potentially extend core life.

In addition, 10 Siemens Perfect Harmony air-cooled VFDs are currently installed in plant condenser circulating water systems. These VFDs provide enhanced pump control, which can assist in meeting the requirements of the Environmental Protection Agency's Rule 316(b) of the Clean Water Act, intended to protect against fish and aquatic life mortality, to support the ability to increase flow and unit output to help avoid plant de-rating due to approaching or exceeding environmental thermal discharge limits, to contribute to improved unit reliability during severe weather events by minimizing water intake blockage, to provide for flexible plant operations to meet varying grid demands, and to reduce motor wear.

Smaller medium- and low-voltage VFDs are also used in other plant applications to control heater drain pumps, water reclamation pumps and charging pumps.

7. *What self-diagnostic features have been considered in digital equipment supplied by AREVA NP?*

AREVA NP's TELEPERM® XS integrates extensive self-monitoring features into its system platform.



AREVA NP's TELEPERM® XS – supplied or on order for 80 units in 16 countries.

These features were described in the TELEPERM® XS Topical Report, and were reviewed and accepted by the NRC. Plant-specific applications have also been reviewed and accepted by the NRC, such as those used for the upgrade AREVA NP completed at Oconee. These online, self-testing and diagnostic functions also improve the availability of the system and significantly reduce maintenance burdens.

The system software on all processing modules, I/O modules and communication modules periodically performs comprehensive tests of the hardware. This includes functionally exercising and testing CPU instructions and checking that the software stored in memory is unaltered. These tests are executed in the background, silently and without interruption. The application software monitors the completion of self-diagnostics within a set time and announces non-completion. Over and above that, hardware watchdogs supervise the non-interruption of the application software by the self-monitoring. System software and communication modules implement end-to-end protection of data integrity. Likewise, processing modules and I/O modules continuously supervise each other.

The TELEPERM® XS platform components are also designed to exhibit fail-safe behavior and error confinement. When self-monitoring detects a fault, the I&C system immediately degrades to a safe back-up mode of operation and announces the failed component to the operator. TELEPERM® XS cabinets feature whole-cabinet monitoring units. Should it occur, these units announce the failure of all modules, including the failure of low-complexity modules such as fans.

8. *What digital systems have been implemented at nuclear power plants worldwide to upgrade the plants to 60-year plant life, enhancing reliability and failure prediction of critical plant components?*

Worldwide, customers at 80 units have implemented or ordered TELEPERM® XS for 43 sites, in 16 countries and for 14 different reactor supplier types.

Contact: Jesse Geris, AREVA, telephone: (434) 832-4392, email: jesse.geris@areva.com. ■

Modernizing French Safety I&C

By Jean-Michel Palaric, Romain Desgeorge and Arnaud Duthou, Rolls-Royce.

Jean-Michel Palaric

As Technical director of the nuclear I&C business of Rolls-Royce, Jean-Michel PALARIC leads the development of technologies and skills in compliance with safety and quality objectives. Jean-Michel has been working in this business unit for more than 20 years.

Before taking this position, Jean-Michel served as a project manager and technical manager on international I&C projects.

From Analogue to Digital I&C Systems

Under EDF's "Grand Carénage (Major re-fit)" industrial program, which aims to extend the operation of nuclear power plants across France beyond 40 years, Rolls-Royce is currently performing two distinct Safety I&C modernization projects, with Areva for EDF. These two projects concerns the EDF'S 900MW fleet (34 units) and 1300MW fleet (20 units).

In France, the nuclear reactor life is milestoned by the ten-yearly inspections (Periodic Safety reviews – PSR) undertaken under ASN, the French safety authority, oversight.

Ten-yearly inspections consist of a comprehensive check-up, which lasts for several months and involves thousands of people.

For the 1300MW PWR fleet (20 units) of EDF, the third ten-yearly inspections are scheduled between 2015 and 2024.

The 1300MW fleet is key to french power generation and its original design authorizes: a potential life extension from 40 to 60 years and an up-rate of around 7%.

In 2009, after a comprehensive survey, EDF assessed the health status of the reactor Instrumentation and Control (I&C) systems of its 1300MW fleet.

Based on this assessment, EDF decided on September 2009 to make feasibility study about the modernization of the reactor I&C of its 1300MW fleet.

The result of this feasibility study was the decision of modernizing the reactor I&C systems with the following scope:

- Replace the programmable part of the reactor control and protection system.
- Add some ESFAS(Engineered Safety Feature Actuation System) actuations to improve safety and keep the same technology (hard-wired) for the voting logic.
- Add screens to help the operator and bring more valuable and easy to use information to his attention.
- Keep the same instrumentation and actuators.

The challenges to be met for such large scale (20 units) and long term project (2015-2023 and 20 scheduled outages) were:

- To adapt the new equipment to existing interfaces (electrical features, cabling, room, power supplies, etc.).
- To be licensable in the time-schedule, according to French law: last document to be reviewed by ASN (The French Nuclear Safety Authority) has to be submitted one year before authorization delivery.
- To be installed in place of the existing operated equipment.
- To be installed and commissioned during the scheduled outages without increase of their durations.
- Being able to support and maintain the equipment for the remaining 30-year lifetime of the reactor fleet (till 2054).
- Being able to integrate the modifications requested by a potential up-rate.

After a one-year basic design, EDF decided to sign a global contract with Areva as main contractor, and chose Rolls-Royce to deliver the technology for the Reactor Protection System (RPS) and Neutron Instrumentation System (NIS) with Spinline® technology, and Rod Control System (RCS) with Rodline® technology.

Hereafter is the architecture of the original I&C systems (see Figure 1):

- Reactor Protection System (RPS) – in grey background
- Neutron Instrumentation System (NIS) - in green background
- Rod Control System (RCS) – in brown background

The solution proposed by Rolls-Royce consists in modernizing, replacing or removing some cabinets. The cabinets

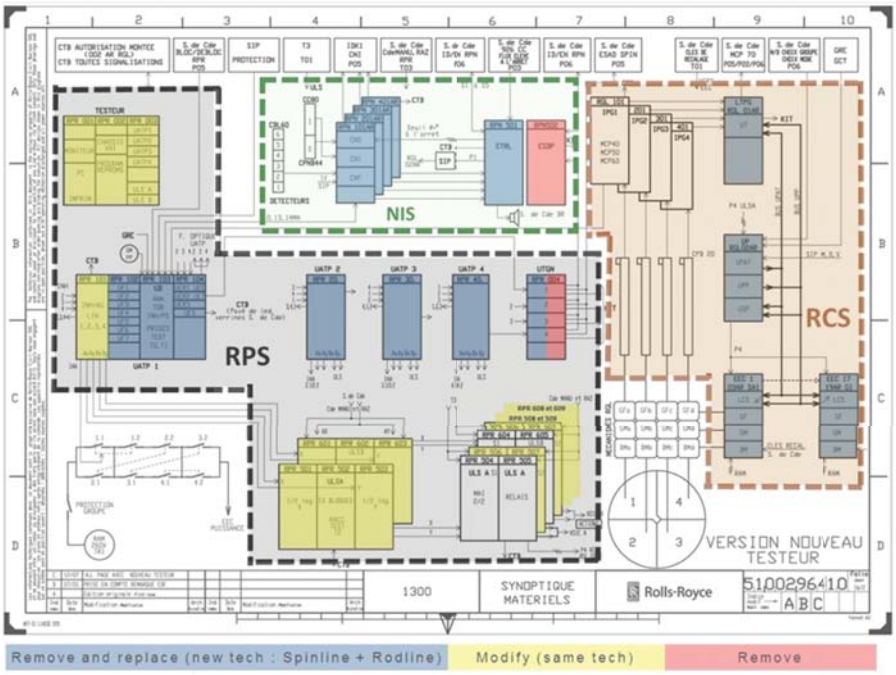


Figure 1. Old and new architecture.

in Blue in the diagram are replaced by new cabinets using the Spinline and Rodline technologies. Cabinets in Yellow are modified using the same technology as in the original system. Cabinets in red are removed.

For this project, Rolls-Royce developed new modules, including boards and terminal blocks, to adapt the equipment to specific interfaces and to ensure the life extension until 2050+. In this framework and as an investment, Rolls-Royce also improved the engineering design environment and developed others components.

All these new designed pieces of equipment required to be specified at an early stage of the project (basic design) so that the first specimen to be manufactured can be qualified through test queues according to the hardware qualification time schedule. It also implies, to manage the risk of this parallel engineering that the data package on existing installations is reliable and the guidelines for new design to be included in Spinline platform are robust to have a high probability to meet the qualification criteria during the tests.

For the licensing process, Rolls-Royce had to support EDF, the licensee, for the demonstration of Spinline's ability to implement 1E safety classified functions, the demonstration of the conformance with IEC 60880, *Nuclear power plants - Instrumentation and control systems important to safety - Software aspects for computer-based systems performing category A functions*, and the acceptability of the architecture after the implementation of the modifications.

For the item on technology, the evaluation was conducted by the safety authority through the following aspects:

- Structure and concepts of Spinline platform (origin, return of experience etc.).
- Design process.
- Mechanisms ensuring a conform operation of the Spinline platform, in particular its determinism.
- Tools to design applications or systems using Spinline platform.
- Technical aspects of the independent V&V of the design of the Spinline platform.
- Reliability of the hardware.

Rolls-Royce supported EDF by providing documentations - more than 8000 pages, welcoming audits, answering to requests for additional information, and by delivering source codes to be tested against their robustness.

For the item on applications, Rolls-Royce effort included three main axes:

- For the Hardware qualification, a 3 steps process was set to demonstrate that the new Spinline cabinets meet the requirements (seismic, EMC [Electromagnetic Compatibility], temperature etc.) through a seismic test of a fully loaded cabinet to determine component acceleration spectrum, tests of all type of components used in systems and final synthesis report combining the test results to demonstrate the conformance with the requirement. This process involved 370 electronic boards, 33 racks, 18 cabinets (off-the-shelf & Spinline) and more than 12 km of cables set up in 5 different labs during 1 year. Also, 150 documents (about 36,000 pages) were released to support, trace and sum up this complete hardware qualification process.
- For software, design of applications according to IEC 60880, and independent test of robustness of the codes generated, with tools such as Frama C by EDF.
- For systems, design with respect of IEC 61513, *Power plants - Instrumentation and control important to safety - General requirements for system,* and 62340, *Nuclear power plants - Instrumentation and control systems important to safety - Requirements for coping with common cause failure (CCF)*, supply of a full scope interconnected test platform (53 cabinets interconnected through 30 km of cables and simulators) and support to a 12 month functional test campaign.

To prepare the installation and to assess the feasibility to replace existing equipment during a scheduled outage, a complete exercise was performed to determine the duration of the installation and the connection with the existing cables added with new ones, optic fibers for instance. Representative mock-ups of the most complex cabinets were manufactured, identical site cables were procured and installation staff performed real connections. Thanks to this exercise, a complete and detailed map of the cabling inside each cabinet with some slight design improvements of cabinets (additional electrical trunkings, change

(Continued on page 32)

Modernizing French Safety...

(*Continued from page 31*)

reconnected to the grid on October 25th and November 19th respectively. Deployment will continue on the next units until 2023.

The ability of Rolls-Royce to deliver architecture based on the existing one (2 out of 4) with no major changes, but based on modern technology

Spinline technology.

of some types of terminal blocks) and real measured durations for connecting cabinets.

In 2016, Rolls-Royce has installed and commissioned these I&C systems on to the first two reactors at Cattenom and Paluel nuclear power stations in France. Both reactors were successfully

(32bit microprocessor, 10mb network, communication gateways) has been really important on this project. It was easier to demonstrate that the system is more effective than the existing one and meets at least the same requirements in term of safety and to interface with modern man machine interface with a

New UATP cabinets using Spinline technology.

guarantee of non-disturbance to safety, thanks to networks, fiber optic, and proper hardware and software architecture.

Rolls-Royce knowledge inherited from the almost 30-year support of the existing system benefits EDF in the quick understanding of the huge amount of detailed requirements during the basic design phase (one year), the design of solutions directly embedding the return of experience.

Moreover, the capability to design new specific safety hardware to adapt its Spinline technology to the existing interfaces in the tight time schedule was also a great value: no need to impact/ modify the installed equipment and so minimize the risk of a too large scope to be implemented during the scheduled outages.

For the 900MW PWR fleet (34 units) of EDF in France, the fourth ten-yearly inspections are scheduled between 2017 and 2027.

In 2016, Rolls-Royce has been awarded a contract to modernise the safety-critical Neutron Instrumentation Systems on 28 of the 34 nuclear reactors in EDF's 900MW fleet in France.

The contract, spanning 16 years, will ensure that the EDF fleet continues to meet increasingly stringent national and international nuclear safety standards. It will see existing analog systems replaced with Rolls-Royce Spinline technology.

The Spinline-based Neutron Instrumentation System is already installed on more than 80 reactors worldwide.

These two projects are managed and operated from the Rolls-Royce I&C Centre of Excellence based in Grenoble, France.

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New Sensors for Small Modular Reactors

By H.M. Hashemian, AMS.

H.M. Hashemian

H.M. "Hash" Hashemian is President of AMS; an international engineering firm established in 1977 and specialized in testing and qualifying nuclear plant I&C systems. He holds a Ph.D. in nuclear engineering, a Doctor of Engineering degree in electrical engineering, and a Ph.D. in computer engineering. He is the author of 3 books, more than 300 papers, and over 20 patents.

Introduction

Small Modular Reactors (SMRs) are at the forefront of new reactor development and implementation in the United States and a few are slated for operation in about a decade. For example, the Idaho National Laboratory (INL) area has been mentioned as the site of the first prototype SMR to be built in the U.S. and begin operation well before 2030. The Utah Associated Power System's Carbon Free Power Project is behind the launch of this plant and has selected the NuScale reactor which is a natural circulation type integral pressurized water reactor.

SMRs are different than conventional nuclear power plants and therefore need different measurement methods, new sensors, and alternative sensor installation mechanisms. Examples of differences between SMRs and conventional reactors which can affect the instrumentation and control (I&C) sensors are: 1) the vessel's internal structure and compact geometry which limit the size, number, and placement of the sensors; 2) operating regimes which present new challenges especially in measurement of primary coolant flow and reactor vessel level; and 3) environmental conditions around I&C sensors including the potential for placing some of the sensors underwater. Furthermore, I&C capabilities must be enhanced for SMRs to enable these plants to operate with reduced number of operation and maintenance (O&M) personnel and facilitate plant availability for an operating cycle that could be much longer than the current fleet of reactors. Figure 1 provides examples of some of the unique SMR I&C challenges.

With a grant from U.S. Department of Energy, AMS is conducting a research and development (R&D) project that is aimed at development of new sensors, adaptation of existing sensors, evaluation of wireless sensors and related technologies, assessment of emerging sensors, and development of sensor qualification standards for nuclear safety-related applications in SMRs. A few of these activities are presented in this article.

Background

As in conventional nuclear power plants, SMRs are expected to require numerous sensors for the control of the plant and monitoring of its safety. This requirement competes with the limited space that is available in current SMR designs; especially if the existing generation of sensors is to be used. Furthermore, the existing generation of sensors is not designed for some of the unique requirements of SMRs. For example, the measurement of primary coolant flow in a pressurized water reactor is relatively straightforward because the technologies for measuring flow through dimensional pipes is well established. However, due to the complex geometries inherent in some SMR designs, the flow paths are radically different and do not favor conventional flow measurement methods. Therefore, the focus of the DOE project is on flow sensors for SMRs in the first place and then on temperature, pressure, and level sensors.

Also, it is anticipated that wireless sensors and digital I&C technologies, specifically those with diagnostic and self-calibration capabilities will be employed in SMRs. These technologies have been used in industrial markets such as oil and gas refinement, chemical, manufacturing, and fossil power production, but not in the nuclear market. This is due largely to sensor manufacturer's reluctance to push their products through the complex and expensive nuclear qualification and regulatory process. The dawn of SMRs is an opportunity for these new technologies to find their way into the nuclear plant I&C arena and provide not only precise, accurate, and fast sensors but also advanced sensor diagnostics and predictive maintenance capabilities. These capabilities typically depend on the output of process sensors during plant operation not only to measure process variables, but also to provide information about the health, reliability, and

(Continued on page 34)

New Sensors...

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performance of the sensors themselves and that of the process. For example, core flow anomalies, flow blockage, and vibration of reactor internals can all be detected by analysis of signals for process sensors.

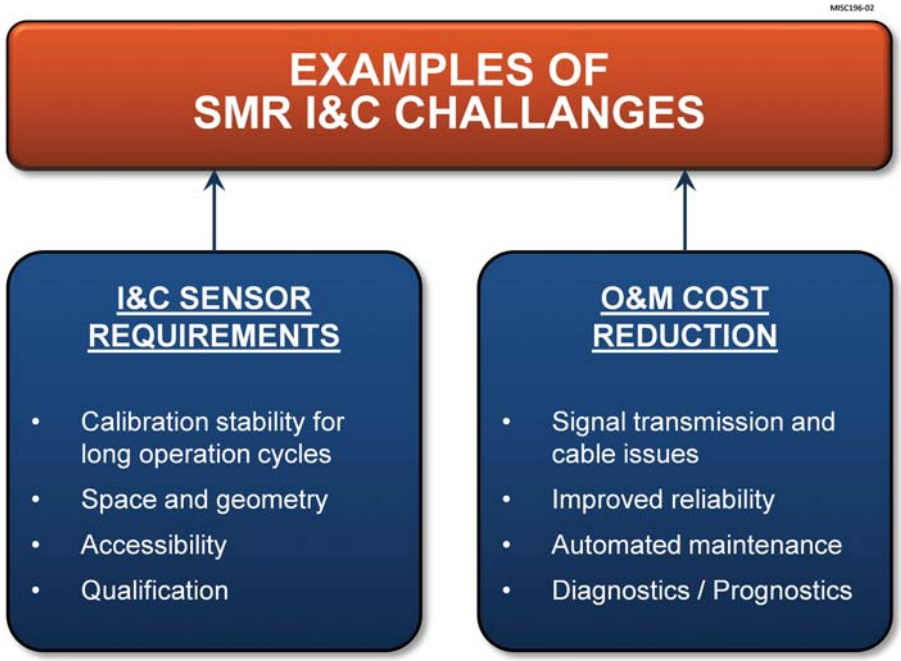

Figure 1. Examples of SMR I&C Challenges.

New Sensors

The following sensors are examples of those that are under development or evaluation through the DOE project at AMS:

1) **Triple Temperature Sensor:** Triple temperature sensors may be made of two thermocouples and one RTD. This type of sensor provides the capability to measure a wide range of temperatures while providing built-in diversity and fault tolerance. The assembly will include electronics and a microprocessor to provide signal conditioning to verify the sensor's calibration and response time. Figure 2 shows a conceptual block diagram of this sensor. The calibration of the sensor is verified by the cross-calibration technique and its response time is measured using the well-known Loop Current Step Response (LCSR) method.

2) **Thermocouple for Temperature and Flow Measurement:** Thermocouples can be made to measure temperature, fluid flow rate, neutron flux, and water level – all in the same sensor. In the DOE project, however, we have focused the R&D on thermocouples for just temperature and flow measurement to keep the scope of the project manageable.

   In the early 1990s, AMS successfully demonstrated the feasibility of a thermocouple to measure both temperature and fluid flow rate. This work was a feasibility study funded by the U.S. Nuclear Regulatory Commission (NRC). The goal of the NRC was to determine if ambient airflow direction and rate can be measured to track airborne radiation in nuclear facilities. The results of this research are documented in NUREG/CR-6334, *New Sensor for Measurement of Low Air Flow Velocity Phase I Final Report.*

   The air flow measurement feature of the thermocouple was demonstrated by testing the response time of the thermocouple in a number of flow rates using the LCSR method. The LCSR method provides for in-situ measurement of response time of an installed temperature sensor and has been used for RTD and thermocouple response time testing in both the nuclear and aerospace industries. The work under the DOE project is building on the success of the NRC project as documented in NUREG/CR-6334 to adapt thermocouples for not only temperature measurements in SMRs but also fluid flow measurements.

3) **Virtual Sensors:** Virtual sensors are created by a combination of measurement and analytical work involving empirical and/or physical modeling. They are used in the current generation of nuclear power plants to provide a reference for instrument calibration verification and provide analytical redundancy for existing sensors.

   For SMRs, virtual sensors will be created in the same way. For example, a process variable may be identified by measurement of two or more other parameters. With physical modeling, first principle equations are used to calculate the desired variable using other measurements, material properties, and plant geometry. With empirical modeling, such tools as kernel regression, neutron networks, or other data-driven modeling techniques will be used to train the software during normal operation and use it to estimate the value of a variable at other times.

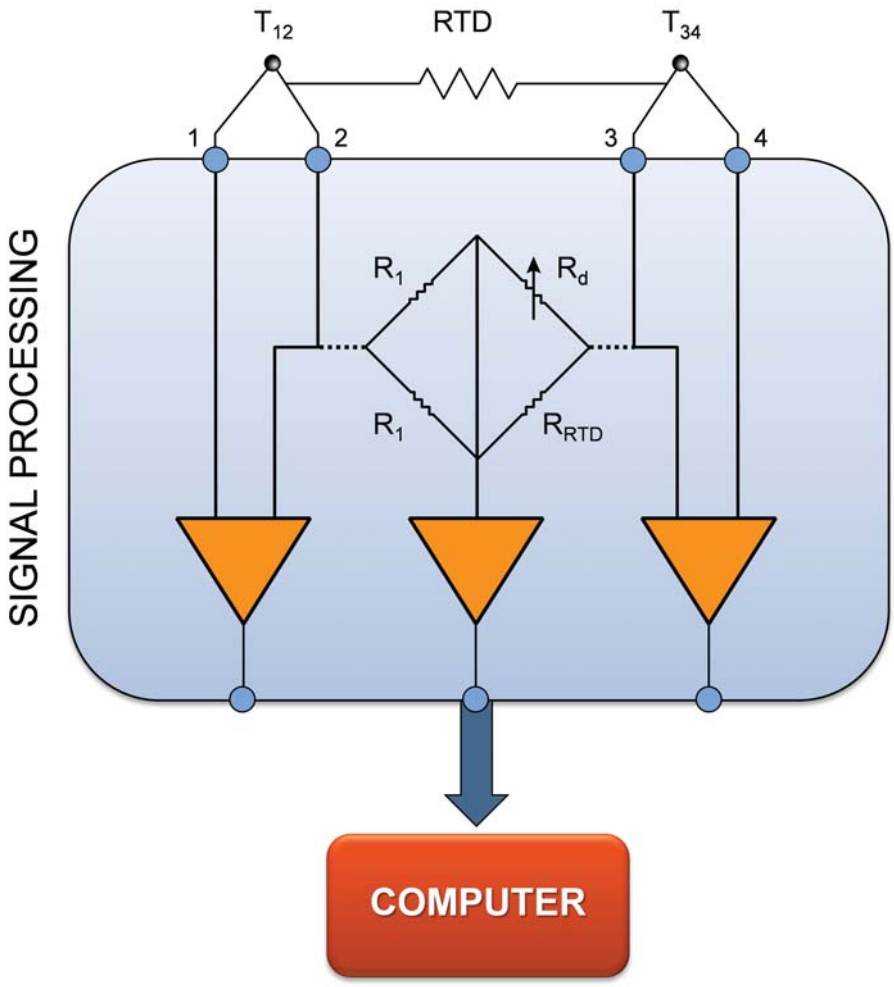

Figure 2. Triple Sensor and Data Acquisition and Analysis System.

4) **Cross Correlation Flow Sensors:** Figure 3 illustrates the principle of cross correlation flow measurement. Basically, signals from any two sensors that are located a distance apart can be cross correlated (i.e. multiplied) to measure the time that it takes for the fluid to travel between the two sensors. This time is referred to as the transit time. The distance divided by the transit time is the fluid flow rate. This method is used in a number of nuclear power plants such as the Comanche Peak Nuclear Station in the United States and Sizewell B Nuclear Power Plant in the United Kingdom to monitor primary coolant flow rate. In these plants, pairs of N-16 gamma sensors are installed on the outside of primary coolant pipes to measure flow by cross-correlation of N-16 signals.

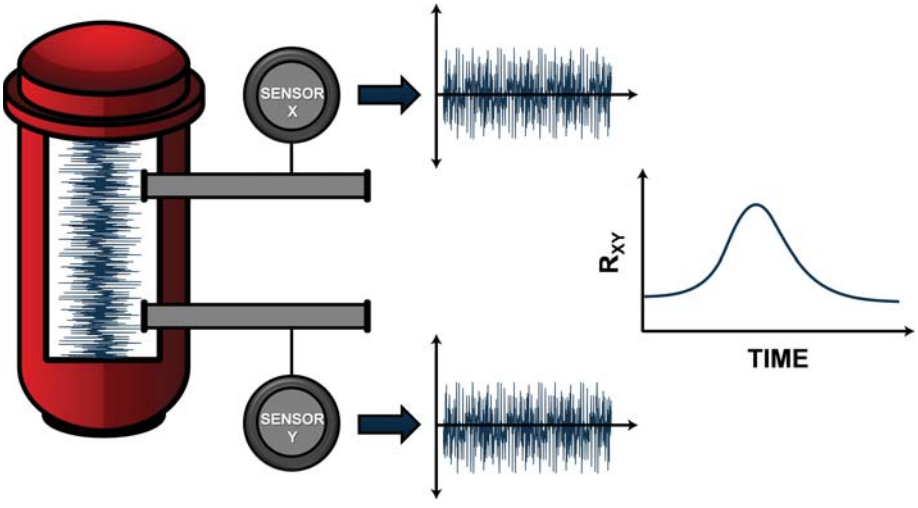

Figure 3. Principle of Cross Correlation Flow Sensor.

5) Wireless Sensors: These sensors can serve SMRs for measurement of process variables as well as for equipment condition monitoring [e.g. vibration measurement for predictive maintenance]. In 2012, a wireless sensor network was installed in the containment of the Arkansas Nuclear One (ANO) Power Station for measurement of vibration of the massive containment cooling fans. In doing so, the electromagnetic compatibility (EMC) and cyber security issues with the use of wireless networks were successfully resolved and the plant has been using this system for over four years. In fact, the success of this project led to ANO installing another wireless monitoring system in the reactor containment. This second system was installed at ANO in 2013 to measure the level of oil that spills into a reservoir inside the containment from the reactor coolant pumps. These and similar other projects have demonstrated that the interference, cyber security, and other issues with wireless technologies are not insurmountable even for applications within the reactor containment.

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Cultures of Trust

By Nigel Thornton, Michael Corum and Sean Clark, Atkins.

Nigel Thornton

A Chartered Civil and structural engineer, Nigel has over 30 years' experience working in the nuclear industry and through his varied experience in construction and engineering is a firm believer in collaborative, relational based contracts. He joined Atkins in 1987 and was instrumental in the development of the office in West Cumbria and building the relationship with Sellafield.

In 2001 ACKtiv Nuclear, a JV between Atkins, Jacobs and Carillion was formed to undertake decommissioning work on the Legacy Ponds at Sellafield, U.K.. Nigel was the Atkins lead in setting up the JV and negotiating the Alliance contract with Sellafield. This was followed by leading the Atkins team, working in a pan-European JV that successfully bid for the Architect Engineer role on the ITER project in France.

Nigel relocated to Charlotte NC in 2012 to lead the development of the Atkins nuclear business in the USA. Following the successful acquisitions, of Nuclear Safety Associates in 2014 and the Energy Solutions PP&T business, in 2016, the Atkins business in the USA is now over 4000 people, including over 800 people in the nuclear sector.

An interview by Newal Agnithori, Editor of Nuclear Plant Journal, at the Utility Working Conference in Amelia Island, Florida in August, 2016.

1. *How do we develop the mutual trust between two corporations?*

Nigel Thornton: Atkins works in successful partnerships all around the world with our clients, governments and industry partners. Fundamentally, successful partnership start with building trust amongst the people who will be working together and this includes executive level commitment to building a mutually beneficial, trusting relationship. These relationships don't necessarily happen overnight; you have to work hard to earn and retain each other's trust and stand by them when faced with increasing complexity or even adversity. We always want to sit side by side with our partners, listening, sharing knowledge, leaning in to challenges and co-creating the best solutions. The Integrated Project Delivery model is best utilized where you've got a program of work over a number of years, and you can benefit from the building of trust over this long period of time. When you have spent years supporting operators across the lifecycle of a fleet or an asset it means you understand your clients' goals and can share their vision. Being open, prepared to listen and prepared to work with other people's ideas are key; it is important to not stifle people's imagination and innovation. Both corporations have to be prepared to be fully open book and not to hide anything. It's also important to challenge each other and push boundaries; in this environment you learn lessons together, drive the best solutions and can constantly feed these back into the design of new or maintenance of existing projects.

Behaviors in delivering and in administering the contract are also key. We thrive on the technically challenging, innovative pieces of a project and constantly look for new techniques and approaches that can add real value. So, if for example you take our work with EDF Energy in the UK, supporting the existing AGR fleet, we have worked with them for over 20 years and we now know how that business works, and we know what it takes to be successful in that business. On what was called the Japanese Emergency Response Program, we were in a joint team with EDF to help avert a Fukushima scale incident in UK. Working collectively and collaboratively on the program we were able to save significant amounts of money. Now, that's the sort of thing that really builds trust: once you know that your supplier is actually trying to find ways to help your business and is not just doing things for the sake of it. Equally when there is something innovative that can be done up front that might cost more than the original specification but that will reduce costs later in the life of the project, it shows your supplier is thinking for the client.

2. *With so many different countries, so many different cultures, do you have a department which addresses the challenges and then comes up with the solutions that this is how you deal with this country?*

Thornton: We have offices all around the world and Atkins has respect for different cultures embedded into our DNA. That's a fundamental. Anywhere we work, we make sure we take time to understand the culture.

We have an office in India, in Bangalore, for example. We have about a thousand people there. They're all local people. The culture of that particular part of Atkins becomes assimilated with the culture of the country in which that division is operating in, whilst also still maintaining the Atkins core brand values and code of conduct. Again, it's down to respect.

Michael Corum: Another example is where we're helping our Japanese client, TEPCO, with the post-Fukushima process. We're involved in setting up their fire protection program for the units that were damaged, as they exist right now. We work in a number of different regulatory environments in the UK, United Arab Emirates, and North America, and it's a great opportunity to bring the best of this experience to our work with TEPCO. In order to do business in Japan, the

first thing we wanted to do was to make sure that it was most convenient for the Japanese client, and all the burden on translation and things of that nature was on us. One of the first things we did was hire full-time Japanese translators who could help us, not only as translators, but as cultural ambassadors. They helped us to understand Japanese culture: how to respond, how to act in a respectful way, down to the point of how to exchange business cards in the Japanese tradition. All of our contact information on the back of our business cards was in Japanese. Any time we interface with them, they speak in their native language, and our translators are there to translate it for us. In any written communication that goes back and forth, it's always in Japanese. The comment has been made to us that 'well, you guys look to us like you're a Japanese company,' and I think that's really one of the highest compliments.

Our guys spend a lot of time in Japan doing walk-downs and they were there on the weekends in certain areas where families had been moved out because of the radiation concerns.

Residents were moving back into the area again, and it was evident, a lot of things had been affected, including their school libraries. All the books were contaminated, and had to be removed. That left a need for books written in English, so that they could teach English to secondary and high school students. One thing that we were able to do as a community was to help supply those English books and that was something that was viewed as very beneficial. We were there, not only as a company doing business, but we were interested in the people in the area and in the well-being of the community. Our employees took it upon themselves to bring the situation to Atkins' attention, and Atkins followed through with the help.

Sean Clark: There'll be a continuing effort there. It's not just the books, but now Atkins is facilitating bringing students and teachers over from the US to Japan and Japan to the US as part of an ongoing program.

Corum: Part of the effort involves the exchanges of letters between school children here in the US and in Japan. When the books were delivered, a message went with them, and one of the American students made a little speech during the presentation, which was well received. This exchange brought the school children together, and those correspondences are ongoing. There's going to be some follow on community service that we're going to provide as time goes on. We're planning on staying active in the community there.

3.: *Control or collaboration.*

Clark: It's a balancing act. Historically, utilities have controlled all the work, and generally they tell the vendor what they want them to do, how they're going to do it, and you respond to what the utility wants. In some cases, the vendors might be better suited to determine how to respond to that problem and fix it but the utility chooses not to use that part of the vendors' capabilities. So now, the question is how does the utility honestly assess its own capabilities and then say I need help; I need the help of a vendor who collaborates with me to fix the problem. I'm looking at them as a partner. At this particular point, that's where subtle shifts are happening.

4. *How does current technology help collaboration at Atkins?*

Thornton: We operate a global business, so internal collaboration and talking with teams from all over the world is crucial for us to do our business. All our telecoms are over the internet, using Skype. For example, the new airport in Jeddah, was a project that involved parts of Atkins from the US, from the UK, from the Middle East and from India. We were across many time zones, many cultures, and delivering all the detailed engineering for the new airport to a very tight timetable.

Michael Corum

Michael Corum is the Vice President-Operations Commercial Nuclear and Specialty Engineering at Atkins.

He was an engineer performing non-reactor nuclear safety analysis at Westinghouse Electric Company from 1992-2001. As a Senior Engineer, he performed core design and reactor reload safety analysis for J.M. Farley Unit 2, performed criticality safety analyses for spent fuel pools and spent fuel transportation casks, performed shielding design calculations for new reactor designs and spent fuel transportation casks, performed criticality safety evaluations for the Westinghouse Columbia Fuel Fabrication Facility.

Corum has a BS and MS in Nuclear Engineering from the University of Tennessee.

He was the Captain of the United States Air Force from 1981 – 1989,

We're acting as one organization, utilizing technology: things like Skype for technical webinars and communications, our internal social media site Yammer for team knowledge and innovation sharing. Face to face conversations are still hard to beat as a way to collaborate but we find technology enhances this channel further as we can share increasingly detailed models and data with the local team face to face and join in our remote teams through Skype. BIM modeling for 3D modeling, animated sequences and walk-throughs, augmented and virtual reality and a whole host of other technologies all support learning and engagement for staff, operators and other stakeholders. Our advanced modelling and analysis tools provide our teams and our clients

(Continued on page 38)

Cultures of...

(*Continued from page 37)*

with the highest levels of accuracy and transparency. This certainty and accountability combined with the integrity of our experts means better judgement of priorities, good collaborative discussions about the options and confident decisions. This builds trust, trust builds even better collaboration.

Internally, we are driving collaboration through a culture we call One Atkins. This ensures that we have a seamless way of doing business across our regions so that we don't have different processes for design and so on; technology plays a major part in this. Our clients are becoming, more and more, global clients. And so, when they've had a good experience with Atkins in the US and they've got something going on in China, they expect a similar experience with Atkins in China. We have to make sure that we are fully joined up to be able to do that.

We want to open people's minds to working in a way which is more collaborative, more long-term in its relationships between vendors, suppliers and the utilities, to everybody's gain, so that ultimately, we're all working to the measures that the utilities are measuring themselves against. We're excited to be part of that. Atkins is keen to play a major role in what is a very, very challenging market.

5. *Based on your experience so far, what are your expectations of the utilities, or a "wish list"?*

Thornton: I think an open mind about the way in which business could be done to the mutual benefit of the industry, right across, all the vertical slice of utilities, vendors, suppliers, subcontractors is the most important.

Sean Clark

Sean Clark is a Director of Business Development for Atkins Energy, responsible for business strategy, client and industry relations, and the development and implementation of innovative solutions. His 40 years of energy industry experience includes nuclear plant design engineering management, INPO, domestic and international project development, and major OEM and EPC business solutions management.

Sean received his BS in Mechanical Engineering from Virginia Tech.

Clark: I think that the nuclear industry must be willing to look outside for solutions because, as an industry, managing commercial aspects of business is something that could be done better. We need to be open, as an industry, to new ways of doing business.

Corum: The nuclear industry needs to look at things collaboratively and look for solutions on a collaborative basis, rather than somebody finding a solution, and then everybody going out and bidding on that particular solution. I think there is a lot of room to learn about how other industries can stimulate creative thought processes that can be incorporated into a collaborative solution. We look forward to bringing some of those learnings from other industries that we capture from across the wider Atkins group and other nuclear industries we work in across the world to help continuously evolve methods and approaches in the nuclear industry here in the US.

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Severe Accident Simulation

L3 MAPPS is making significant technological advancement with each successive implementation of Electric Power Research Institute's (EPRI) Modular Accident Analysis Program (MAAP) to model postulated severe accidents on real-time training simulators.

Background

A severe accident can occur if a loss of fuel cooling is not mitigated in time. L3 MAPPS' thermal-hydraulic model (ANTHEM™) simulates various effects related to loss of cooling such as steam formation, core heat-up, fuel failure and hydrogen generation. However, the primary assumption in ANTHEM™ is that there is no change in the geometry of the fuel or the surrounding structures. If such conditions must be simulated, then additional codes are required. Therefore, for the purposes of real-time simulation, a severe accident is defined as any initiating event whose evolution results in a change of geometry of the fuel or the surrounding structures.

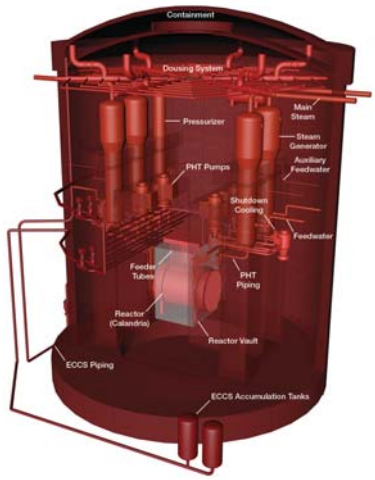
In the year 2000, on Nuklearna Elektrarna Krško's full scope simulator (PWR; Slovenia), L3 MAPPS conceptualized and created the basic architecture for the MAAP integration into L3 MAPPS' simulator environment. In recent years, following the Fukushima incident, the demand for severe accident simulation increased. In 2011, L3 MAPPS developed a standard interface scheme allowing graphical connections between MAAP and the simulated boundary systems. A new MAAP library, consisting of various hydraulic and I&C interface objects, was created within L3 MAPPS' Orchid® Modeling Environment.

In 2013, during the Ling Ao Phase II severe accident simulation project (PWR; China), a standard MAAP synchronization module and driver were deployed. On the same project, new 2-D and 3-D visualizations were added to the PWR models to provide operators and emergency response organizations with better insight into the simulation. The severe accident progressions can be visualized with the core with various degrees of fuel melting, slumping of core material in the lower plenum and the failure of the reactor vessel. 3-D visualizations of the spent fuel pool (SFP) were also created to show severe accident progressions involving the heat up and melting of the spent fuel assemblies in the SFP. These technologies and methodologies were applied to several other PWR simulator projects. The most recent advances include the implementation of the MAAP4-CANDU* for a CANDU** plant simulator and MAAP5*** for a BWR plant simulator.

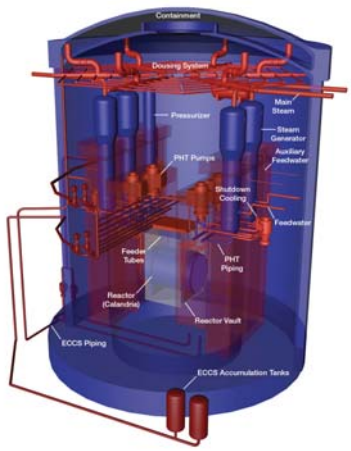
MAAP4-CANDU for real-time CANDU plant simulation

The implementation of MAAP4-CANDU is in the early phase of development, with significant collaboration between L3 MAPPS and Fauske & Associates (FAI), the original MAAP code developer. The portions of the MAAP4-CANDU model used are the reactor, Primary Heat Transport (PHT) system, Calandria, end shields, steam generators and containment building. The L3 MAPPS Orchid® models which will interface with MAAP4-CANDU include the emergency core cooling system (ECCS), shutdown cooling, feed and bleed, moderator cooling, end shield cooling, dousing system, containment HVAC, feedwater, blowdown and main steam. The MAAP4-CANDU source code was recently updated by FAI to include all necessary interfaces with the boundary systems simulated in L3 MAPPS' models. This development simplifies future implementations of MAAP4-CANDU on L3 MAPPS simulators. The integration of the MAAP4-CANDU in the L3 MAPPS simulator environment is projected to finish in the first quarter of 2017. Test case data from stand-alone MAAP4-CANDU will be used as the reference data for the validation of L3 MAPPS' latest CANDU simulator project, the Wolsong 1 full scope simulator (CANDU 6; Korea).

In order to provide deeper insight into the running simulation models, 3-D graphical models of the CANDU plant are being created. The simulator 3-D graphics will be used to visualize severe accident progressions. Using Bridgeworks©, the realistic 3-D mechanical models will include color dynamics and will be animated and highly interactive.



During standard licensed operator training, L3 MAPPS' CANDU models perform all calculations (shown in red).



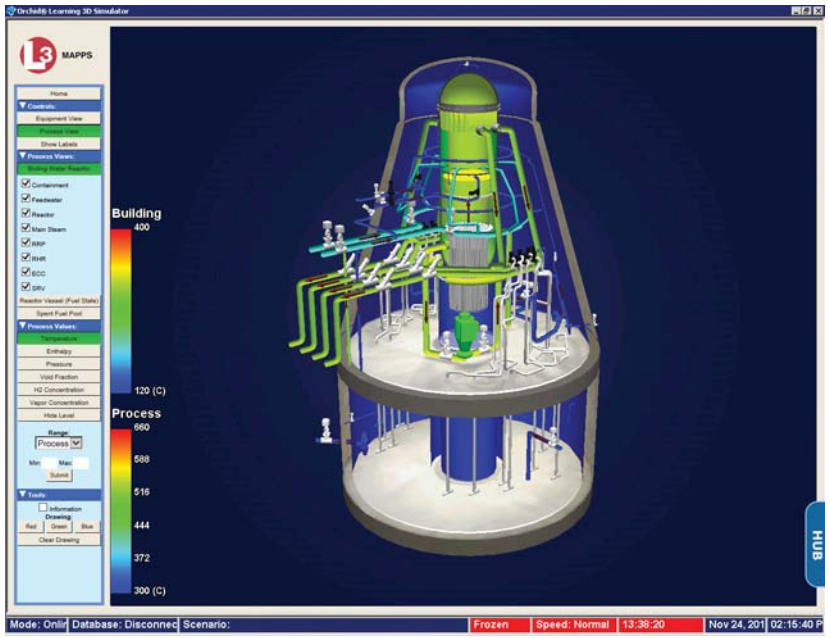
During beyond design basis and severe accidents, MAAP4-CANDU models are engaged (MAAP models shown in blue, L3 MAPPS models shown in red).

*An article from L3 MAPPS' **sim**news, Issue 43, January 2017.*

In CANDU 6 plants, the Calandria is a horizontal tank with fuel contained inside its 380 channels. Its simulation is more complex when compared to the PWR or the BWR. The fuel bundles are contained inside the pressure tubes which are located inside the Calandria tubes. The double-tube channels are located inside the Calandria tank. The 3-D graphics include the Calandria, the steam generators, inlet and outlet feeder tubes, the control rods, the end shields, the poison injection piping, and all the PHT piping depicted spatially accurately in the containment building completed with important support structures and the Calandria vault. In the model, these 380 horizontal channels are divided into groups according to elevation and the power density of the channels and they are further divided into multiple "slices." Critical parameters are driven by MAAP4-CANDU (in severe accident simulation mode) or by L3 MAPPS models (in standard training mode) in each of these subdivisions (or nodes) in the reactor and are shown visually with different colors in the 3-D graphics.

MAAP5 for real-time BWR plant simulation

MAAP5, already employed on several L3 MAPPS PWR simulators, is also being applied to a BWR plant simulator for a project in USA. The portions of MAAP5 used are the reactor vessel, the containment building including the dry well and wet well and SFP. The L3 MAPPS Orchid® models interfacing with the MAAP5 models include rod control, nuclear instrumentation, feedwater, main steam, high-pressure coolant injection (HPCI), reactor core isolation cooling (RCIC), residual heat removal (RHR), core spray, control rod drive system (CRDS), reactor water cleanup, containment cooling/HVAC, SFP cooling, secondary containment and radiation monitoring. FAI has been engaged to make the required modifications to the MAAP5 code in order to assist L3 MAPPS with the successful integration of MAAP5 with L3 MAPPS models for BWRs. During integration, preliminary testing with severe accident scenarios was performed in a working configuration and satisfactory results were obtained. In order to interface MAAP5 with the surrounding ANTHEM™ systems, new interface objects have been created. Due to this development, any L3 MAPPS hydraulic model can easily and visually interface with MAAP in the Orchid® environment. This allows the inputs and outputs to MAAP to be graphically and dynamically represented.



Example of interactive 3-D visualization for BWR plant.

3-D graphics are being developed to monitor and interact with severe accident progressions in the BWR simulation. The 3-D graphics are created using data from plant isometric drawings. Data extracted from the isometric drawings are transformed into spatially correct 3-D representations of the reference plant.

Wrap-up

Due to events in Japan in the wake of the March 11, 2011 earthquake and tsunami, nuclear regulators throughout the world will more closely scrutinize the capability of nuclear power plant operators to manage situations caused by beyond design basis and severe accidents. This close scrutiny will require that operators are trained in handling situations involving severe accidents, and that their training includes knowledge on and experience in performing recovery operations safely. Although the ANSI/ANS-3.5 standard, *Nuclear Power Plant Simulators for Use in Operator Training and Examination*, does not require the use of full scope simulators for such severe accidents familiarization/training, L3 MAPPS continues to see activity in this area.

Contact: Sean Bradley, L3 MAPPS, telephone: (514) 787-4953. ■

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Advanced Reactor Technologies Gain Momentum

Credit: Nuclear Energy Institute.

NuScale SMR Plant Design.

The U.S. House of Representatives unanimously passed the Advanced Nuclear Technology Development Act of 2017 (HR 590, *Advanced Nuclear Technology Development Act of 2017*). The bill is intended to "foster civilian research and development of advanced nuclear energy technologies," enhance their licensing and commercial deployment, and have the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission collaborate in their licensing.

Nuclear Energy Institute President and Chief Executive Officer Maria Korsnick thanked sponsors Rep. Bob Latta (R-Ohio) and Jerry McNerney (D-Calif.) for their strong bipartisan support. The bill's passage has "significantly advanced a major component of America's future energy and technology infrastructure—our nation's innovation-leading advanced reactors," she said.

"This legislation is critical in developing the licensing framework that will allow the United States to develop the next generation of nuclear reactors. America has led the world in commercial nuclear technology for more than six decades, and the licensing framework this bill seeks to create will ensure America's role as the leader in nuclear energy in the decades ahead."

HR 590 is not the only legislation going through the new 115th Congress in support of advanced nuclear technologies. Rep. Randy Weber's (R-Texas) Nuclear Energy Innovation Capabilities Act (NEICA) (HR 431) was included in legislation that also passed unanimously in the House this week. The Senate meanwhile took swift action to introduce the companion bill to NEICA, S 97, *Nuclear Energy Innovation Capabilities Act of 2017*.

The incoming administration also is expressing interest. In former Texas Gov. Rick Perry's confirmation hearing last week for secretary of energy, Sen. Jeff Flake (R-Ariz.) asked how the Department of Energy can work with private companies like NuScale Power LLC and with the NRC to support ongoing research and speed the adoption of new nuclear technologies, especially small modular reactors.

In response, Perry said he finds the concept of small modular reactors "fascinating," and thought not just the private sector but our universities should be brought to bear.

"Small modular and advanced reactors are exactly the types of investments DOE should be making," Perry added.

These new types of reactors have been garnering attention since well before the beginning of 2017, when small reactor developer NuScale Power made news by being the first U.S. vendor to ask the NRC to certify its design. ■

Research & Development...

(*Continued from page 20)*

INL

Advanced II&C Systems Technologies

The Advanced Instrumentation, Information and Control (II&C) Systems Technologies Pathway conducts targeted research and development to address aging and reliability concerns with the legacy instrumentation and control and related information systems of the U.S. operating LWR fleet. This work involves two major goals: (1) to ensure that legacy analog II&C systems are not life-limiting issues for the LWR fleet, and (2) to implement digital II&C technology in a manner that enables broad innovation and business improvement in the nuclear power plant operating model. Resolving long-term operational concerns with the II&C systems contributes to the long-term sustainability of the LWR fleet, which is vital to the nation's energy and environmental security. The Advanced II&C Systems Technologies Pathway research and development efforts address critical gaps in technology development and deployment to reduce risk and cost. The objective of these efforts is to develop, demonstrate, and support deployment of new digital II&C technologies for nuclear process control, enhance worker performance, and provide enhanced monitoring capabilities to ensure the continued safe, reliable, and economic operation of the nation's nuclear power plants.

New value from II&C technologies is possible if they are integrated with work processes, directly support plant staff, and are used to create new efficiencies and ways of achieving safety enhancements. A goal of these efforts is to motivate development of a seamless digital environment for plant operations and support by integrating information from plant systems with plant processes for plant workers through an array of interconnected technologies:

- Plant systems – beyond centralized monitoring and awareness of plant conditions, deliver plant information to digitally based systems that support plant work and directly to workers performing these work activities.
- Plant processes – integrate plant information into digital field-work devices, automate many manually performed surveillance tasks, and manage risk through real-time centralized oversight and awareness of field work.
- Plant workers – provide plant workers with immediate, accurate plant information that allows them to conduct work at plant locations using assistive devices that minimize radiation exposure, enhance procedural compliance and accurate work execution, and enable collaborative oversight and support even in remote locations.

The development and collaborations through this pathway are intended to overcome the inertia that sustains the current status quo of today's II&C systems technology and to motivate transformational change and a shift in strategy – informed by business objectives – to a long-term approach to II&C modernization that is more sustainable.

Contact: Bruce Halbert, telephone: (208) 526-9867, email: bruce.halbert@inl.gov.

Reactor Safety Technologies

To further enhance the safety of existing nuclear power plants, the Reactor Safety Technologies Pathway will expand beyond areas specifically related to the Fukushima accident forensic analysis to incorporate lessons learned from the Fukushima accident into commercial nuclear power plant issues. The safety enhancements expected to result from this program will apply to both prevention and mitigation of accidents (e.g., mitigating strategies for long-term station blackout, venting strategies for beyond design base accidents conditions).

The goals of this effort are to:

1. Identify opportunities to improve nuclear power plant capabilities to monitor, analyze and manage beyond design base conditions to prevent or mitigate severe accidents.
2. Use and improve beyond design base accident progression analyses using existing models and simulation codes to aid in accident prevention and mitigation actions.
3. Inform and engage with Japanese and international partners in the ongoing Fukushima reactor data collection efforts as well as the future reactor inspection efforts, to optimize understanding of severe accidents and to reduce uncertainty around accident progression, for the benefit of U.S. nuclear safety analysis capabilities.

Shown above is an illustration of different flow geometries (MAAP left and MELCOR right) through a degraded reactor core, where the MAAP model predicts the formation of a blockage causing steam flow to bypass the degraded core materials in contrast to the MELCOR model where the blockage is porous and allows steam flow to pass through the degraded core materials.

Contact: Mitchell Farmer, telephone: (630) 252-4539, email: farmer@anl.gov.

The above are research and development highlights from the Idaho National Lab's (INL) Light Water Reactor Sustainability (LWRS) Program in 2016.■

Risk Assessment Process

By Rich Weisband, Exelon Generation.

Rich Weisband

Rich Weisband became Equipment Reliability Senior Engineer, Exelon Nuclear Generation, in May 2012. As Sr. Manager, Equipment Reliability he developed and oversees the Nuclear Risk Management Process and oversees the Exelon Nuclear PM Program and governance.

Weisband joined Exelon in 1982 and has worked in quality assurance, engineering, maintenance, regulatory, operations, work management and held supervisory and manager positions. Weisband earned a bachelor's degree in Mechanical Engineering from the University of Pittsburgh and received a hot license certification at Limerick Generating Station.

Nuclear Energy Institute's Top Industry Practice Awards recognize the nuclear industry's most innovative techniques and ideas.

This innovation won the 2016 Communications Award.

The Exelon team members who participated included Rich Weisband, Senior Engineer; Andy Winter, Senior Engineering Manager, Equipment Reliability; Andrew Brewer, Engineering Manager; Kelly Root, Manager.

Summary

The Exelon Nuclear Risk Management Process (AD-AA-3000) was developed to improve the management of risk issues involving significant risks. (See the *Risk Assessment and Ranking Process* flowchart.) Within Exelon Nuclear there were many tools that assessed risk using different thresholds, processes, and terminology. AD-AA-3000 was designed to be applied to a broad range of issues being evaluated through different processes that represent a significant threat to the business.

This process simplified, aligned and educated the Exelon nuclear fleet on Risk Management including risk recognition and assessment. The process uses one standard for potential consequence levels using the criteria from the Corrective Action Program.

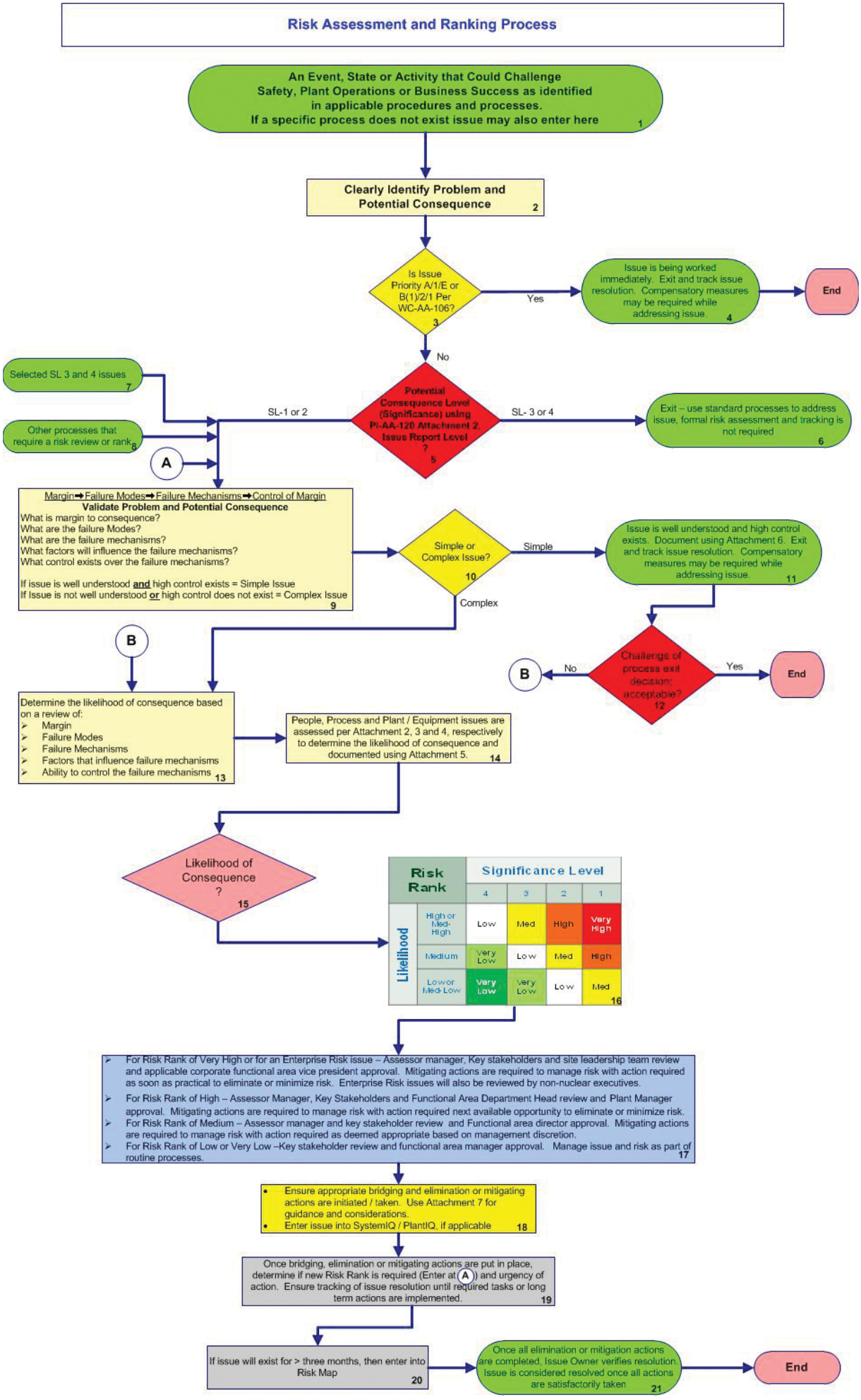
A computer based tool was developed, *Risk Classification Manager* (RCM), to support formal risk assessments and provides for printing or viewing individual risk issue report, risk maps and summary reports as described in the AD-AA-3000 process document. The risk issue report and risk map are generated based on the risk assessment entries in the RCM Tool. The RCM tool has links to the action tracking and work management systems to ensure the standard tracking systems are used to track the resolution of the risk issue and the RCM tool is automatically updated as actions are completed.

The key elements of this process include the following:

1 **Identification of need for risk assessment** – Over 35 processes across the nuclear group have been revised to either eliminate independent risk assessment methodology, prompt the use of the new risk process, and/or ensure proper interface with the new risk assessment process. The key element here was to align the nuclear group to use consistent consequence levels for determining those issues that warrant a formal risk assessment.

2. **Risk Issue Assessment** – Risk issues are assessed by documenting and addressing the margin to consequence, the potential failure modes, the failure mechanisms, the factors that influence failure mechanisms and the identification of a risk management strategy (planned bridging and elimination or mitigation actions).
3. **Determine risk rank and obtain review and approval** – Once the assessment is performed, the risk rank is determined and that will dictate the level of approval required using a graded approach based on the potential consequence and likelihood.
4. **Implement risk management strategy** – Implement the risk management strategy until issue is resolved.
5. **Periodically review risk issues using risk map** – While the risk issue is being addressed, the issues are captured on Risk Maps that are periodically reviewed by management to keep track of the issue and ensure actions are progressing as expected. The risk maps have been incorporated into Exelon standard management meetings, including Plant Health, Equipment Reliability Management Review Meeting, Nuclear Safety Review Board committees, etc…In addition, new management committees were established at the site and corporate level to formally review the site and Fleet Risks; Site and Nuclear Risk Management Committees, respectively.
6. **Risk resolution review and closure** – Upon completion of all the risk management actions that either eliminate or mitigate the risk condition to within the companies risk appetite, the risk issue is reviewed to verify the issue is resolved and then taken to "Resolved" status.

(Continued on page 46)


Risk Assessment and Ranking Process
An Event, State or Activity that Could Challenge Safety, Plant Operations or Business Success as identified in applicable procedures and processes. If a specific process does not exist issue may also enter here 1
Clearly Identify Problem and Potential Consequence 2
Is Issue Priority A/1/E or B(1)/2/1 Per WC-AA-106? 3
Yes
Issue is being worked immediately. Exit and track issue resolution. Compensatory measures may be required while addressing issue. 4
End
No
Selected SL 3 and 4 issues 7
Other processes that require a risk review or rank 8
A
Potential Consequence Level (Significance) using PI-AA-120 Attachment 2, Issue Report Level ? 5
SL-1 or 2
SL- 3 or 4
Exit – use standard processes to address issue, formal risk assessment and tracking is not required 6
Margin➡Failure Modes➡Failure Mechanisms➡Control of Margin
Validate Problem and Potential Consequence
What is margin to consequence?
What are the failure Modes?
What are the failure mechanisms?
What factors will influence the failure mechanisms?
What control exists over the failure mechanisms?
If issue is well understood and high control exists = Simple Issue
If Issue is not well understood or high control does not exist = Complex Issue 9
Simple or Complex Issue? 10
Simple
Issue is well understood and high control exists. Document using Attachment 6. Exit and track issue resolution. Compensatory measures may be required while addressing issue. 11
Complex
B
Challenge of process exit decision acceptable? 12
No
Yes
End
Determine the likelihood of consequence based on a review of:
Margin
Failure Modes
Failure Mechanisms
Factors that influence failure mechanisms
Ability to control the failure mechanisms 13
People, Process and Plant / Equipment issues are assessed per Attachment 2, 3 and 4, respectively to determine the likelihood of consequence and documented using Attachment 5. 14
Likelihood of Consequence ? 15
Risk Rank
Significance Level
4 3 2 1
Likelihood
High or Med-High
Medium
Low or Med-Low
Low Med High Very High
Very Low Low Med High
Very Low Very Low Low Med 16
For Risk Rank of Very High or for an Enterprise Risk issue – Assessor manager, Key stakeholders and site leadership team review and applicable corporate functional area vice president approval. Mitigating actions are required to manage risk with action required as soon as practical to eliminate or minimize risk. Enterprise Risk issues will also be reviewed by non-nuclear executives.
For Risk Rank of High – Assessor Manager, Key Stakeholders and Functional Area Department Head review and Plant Manager approval. Mitigating actions are required to manage risk with action required next available opportunity to eliminate or minimize risk.
For Risk Rank of Medium – Assessor manager and key stakeholder review and Functional area director approval. Mitigating actions are required to manage risk with action required as deemed appropriate based on management discretion.
For Risk Rank of Low or Very Low –Key stakeholder review and functional area manager approval. Manage issue and risk as part of routine processes. 17
Ensure appropriate bridging and elimination or mitigating actions are initiated / taken. Use Attachment 7 for guidance and considerations.
Enter issue into SystemIQ / PlantIQ, if applicable 18
Once bridging, elimination or mitigating actions are put in place, determine if new Risk Rank is required (Enter at A) and urgency of action. Ensure tracking of issue resolution until required tasks or long term actions are implemented. 19
If issue will exist for > three months, then enter into Risk Map 20
Once all elimination or mitigation actions are completed, Issue Owner verifies resolution. Issue is considered resolved once all actions are satisfactorily taken 21
End

Risk Assessment...

(*Continued from page 44)*

Safety Response

This process ensures high potential consequence issues (e.g., reactor scrams, significant outage extensions, plant vulnerabilities) are risk assessed to ensure management has a clear understanding of the risk and plans to bridge and eliminate or mitigate the risk condition. This process has been used to risk assess all the Exelon station's single point vulnerabilities to determine the risk rank and this supported the proper prioritization of the actions to address the vulnerability.

This tool was invaluable in ensuring the higher risk issues are recognized by management and prioritized for resolution.

Cost Savings Response

This process was designed to prevent high consequential events and it is difficult to quantify savings by use of the process. One key measurement of success is the reduction of high consequence issues as measured in the Corrective Action Program. Since this risk process has been implemented and the corresponding increased management attention based on AD-AA-3000 to ensure potential high consequence issues are identified, the average number of events per unit per site has decreased by 20%. This followed stagnant performance for over three consecutive years from 2011, 2012, 2013 through the first half of 2014. An example that highlights the potential prevention of a plant event that most likely, had the event occurred, would have resulted in permanent shutdown of the unit.

During a refuel outage, a routine megger performed on the main generator found low megger readings. This condition was recognized as a significant issue since during the previous refuel outage megger readings had lowered from previous outages and the recent test showed continued degradation of some sub-component on the generator. The potential consequence of a ground condition on the generator could result in catastrophic failure of the generator and result in a long term shutdown of the unit. Based on the remaining station life, this could have resulted in a permanent plant shutdown. Using the risk process per AD-AA-3000, this was highlighted as a very high potential consequence (or Enterprise Risk) and, additional testing was authorized (hi pot test, similar to megger test but at a higher voltage). This was a significant decision due to the potential to fail components on the generator during the test. However, it was also of critical importance to perform this test to identify the component(s) that were causing the low megger readings. As a result, the hi pot test was performed and the failure location was identified and traced to the stator water cooling hoses. These hoses were found to be significantly degraded. As it turned out, this was a relatively simple fix and allowed the generator to be returned to service with confidence that it would successfully operate for the operating cycle.

When we look at our most significant event in the Corrective Action Program (CAP), there were eight events in 2014 as compared to two in 2015. For these very high consequential events, it could be assumed a cost of $2 million. This would equate to a reduction in $12 million savings. In addition, a recent assessment has determined that there has been a reduction in consequential events that were preventable with proper risk management.

Innovation Response

The method used to develop this risk process and the RCM tool that reports the risk was innovative in that this process begins with a focus on first understanding the potential consequence of an issue. Subsequently, a significant number of Exelon management model documents were revised to align the entire organization to one risk assessment process. In addition, the tool used to report the results was innovative in that once issues are placed into the risk assessment tool, that risk maps and risk assessment reports are easily retrievable. These risk maps and other reports generated from the tool allows management to review risks by functional groupings (such as material condition or regulatory) and site risk maps, as well as, fleet risk maps. In addition, further enhancements have been made to the RCM Tool to show movement of risks on the risk map. Also the RCM Tool allows for the grouping of risk issues for use in other processes, such as Operational Decision Making (ODM) issues and Long Term Asset Management issues.

Productivity/Efficiency Response

The most important efficiency gain using this process was to provide a tool for consistent risk assessment and then provide a common reporting system for management to review all site or corporate risks using a consistent ranking scheme. The easily generated risk maps help management observe in one report the risk issues applicable to the area being reviewed and this helps ensure proper resources are applied to the right issues. The savings realized by auto generated maps, as well as the ability to easily adjust, most likely equates to an 8 hour savings per site per quarter. This would equate to over 400 person hours of savings per year. Although with the other uses of the risk maps, being used for many process, the savings in most likely over 1000 person hour savings per year.

Transferability Response

All nuclear organizations have similar risk assessment processes that have been developed over the years. However as was recognized at Exelon, there were different thresholds and processes that resulted in inconsistent risk management; and with multiple reporting schemes that made it difficult to determine or measure risks against one another. The concepts provided in the Exelon risk assessment process can be easily transferred to other organizations using the same basic concepts provided they are committed and have the will to revise many different processes to a single standard as was done at Exelon Nuclear.

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Addressing IGSCC in Turning Vane Bolts

By Gerry Ottman, AREVA and William Murray, Dominion.

Gerry Ottman

Gerry Ottman, Sr. Manager, Innovation & Technology, Component Repair & Replacement (CR&R), AREVA.

Gerry holds Bachelors and Master's degrees in mechanical engineering and is a licensed professional engineer. He has more than 35 years in the nuclear industry, including 17 years as a plant and system engineer at operating PWR and BWR plants. He has been at AREVA since 2003, holding management positions in the Pump and Motor Services, Outage Services, and Component Repair & Replacement businesses.

Nuclear Energy Institute's Top Industry Practice Awards recognize the nuclear industry's most innovative techniques and ideas.

This innovation won the 2016 AREVA Vendor Award.

The team members who participated included Will Murray, RCP Project Lead, Dominion; John Lee, Engineer, Dominio; Alex Bauer, Engineer, Dominion; Chad R. Conrad, Operations Manager PMFS, AREVA.

For more than 40 years, reactor coolant pumps (RCPs) in the U.S. nuclear fleet have operated smoothly. Nonetheless, aging, high vibrations and wear take their toll; intergranular stress corrosion cracking (IGSCC) is of particular concern. One of the most susceptible areas to IGSCC in an RCP is the turning vane (TV) bolts. Failing RCP TV bolt heads could cause the TV to drop, contact the RCP impeller and cause a locked rotor condition. Contact between these components during plant operation could decrease the coast-down time of the RCPs and adversely impact core cooling during certain accident scenarios. All Model 93A RCPs are susceptible to IGSCC, but the early 20-bolt, 1-inch diameter configuration more so. In the United States, only three units use this configuration, while the rest use a 24-bolt, 1.5-inch diameter configuration.

In 2014, Dominion teamed up with AREVA to proactively address IGSCC at Surry units 1 and 2, putting together a plan to refurbish two RCPs at Unit 1 during the spring 2015 outage and three RCPs at Unit 2 during the fall 2015 outage. Dominion's proactive and thoughtful approach to the project – ensuring simultaneous RCP replacements during the normal outage schedule – eliminated potential future equipment problems and allowed them to replace each unit's RCPs with the same resources and equipment in one outage per unit. By replacing all the RCPs in one outage, instead of one per outage for the next three, Dominion saved a significant amount of resource and equipment cost: approximately $5.6 million.

This project posed many unique challenges. The timing for the replacements was too tight to manufacture new RCPs for any of the five units, so the team determined that refurbishing RCPs for use at the Surry units was possible. Two suitable RCPs were obtained from the shutdown Kewanee Power Station. After significant refurbishment and upgrading, these replaced the two RCPs at Surry Unit 1. The two original RCPs from Unit 1 were then refurbished and installed at Surry Unit 2, along with a previously refurbished RCP back-up component. In parallel with these engineering and manufacturing efforts, field implementation teams planned the complex logistics of replacing multiple RCPs during a normal maintenance outage.

The Process

Prior to the beginning of any work, the AREVA and Dominion teams first created full-scale mock-ups for the RCP work plan, practicing all tasks as they are in the field. All members of the team took part in this training, including machinists, station management, engineers, RP and safety personnel. Practicing the critical, high-dose tasks using the mock-ups allowed the team to find the best processes to reduce time and integrate dose savings techniques into the plan. Additionally, a detailed machinists pre-job brief form was developed to decrease the time spent on turnover and briefing, in turn increasing personnel productivity in the field.

The two RCPs with the 24-bolt, 1.5-inch diameter design from Kewaunee were refurbished, modified and upgraded with new computer numeric controlled (CNC)-machined impellers to change the pump flow rates to match that required at Surry. These RCPs required different piping arrangements than those at Surry Unit 1, so plant modifications were needed in conjunction with the RCP exchange. Additionally, resistance temperature detection thermal wells had to be relocated in the Kewaunee RCPs. These refurbishments, conducted by AREVA's team, had to be completed in record time to meet the spring 2015 outage deadline.

The two RCPs removed from Surry Unit 1 were sent to AREVA for a complete refurbishment during summer 2015. New shafts, bearings and bolting were installed in the pumps, and the impellers on the pumps were reused. The refurbished RCPs were returned to Surry in October 2015 and these two RCPs, along with a previously refurbished RCP, were installed at Unit 2 during the fall 2015 outage.

Lessons Learned

Integral to the planning and preparation was extensive mock-up training with AREVA's pump and motor field service team and Surry's maintenance technicians. AREVA's development of new and improved tooling and equipment

(Continued on page 50)

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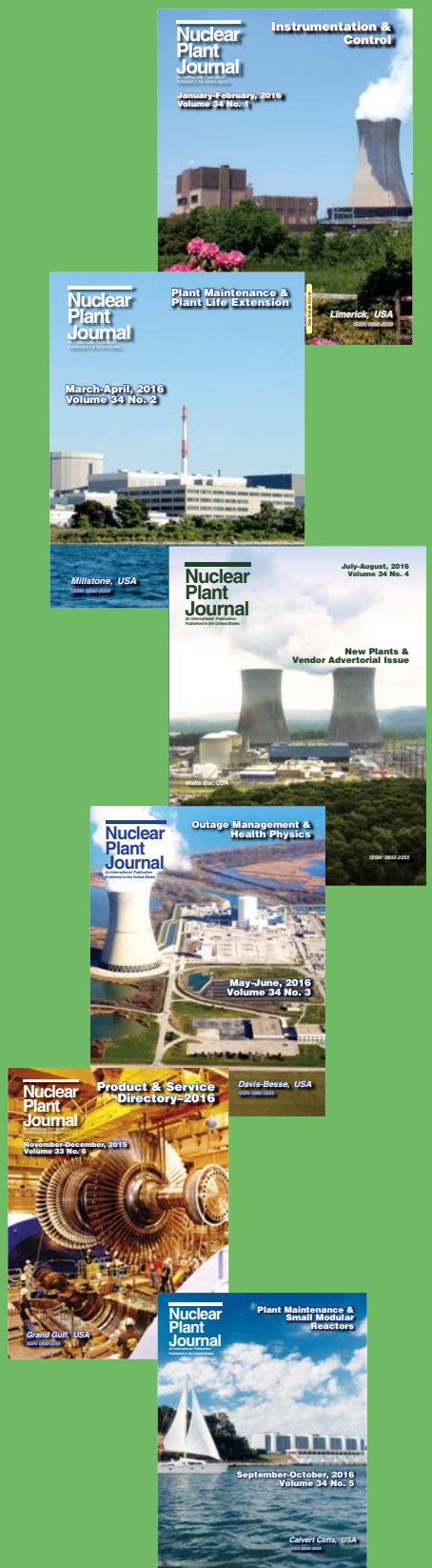

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Addressing IGSCC...

(*Continued from page 48)*

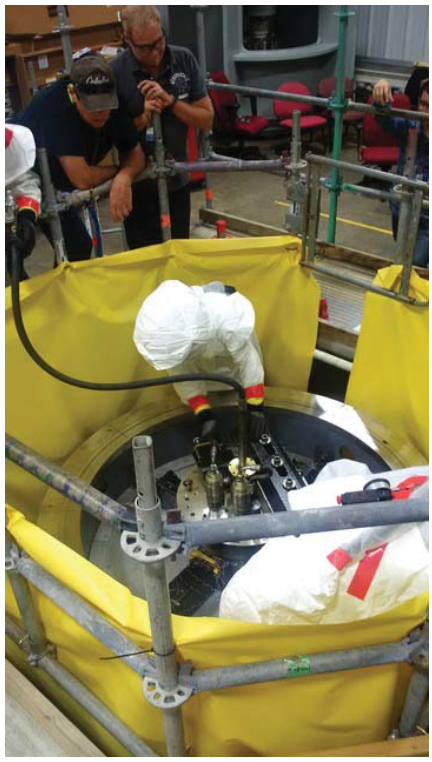
also helped make the process run smoothly and without issue.

In addition, both teams' rigorous focus on safety, the number one priority established during all stages of the project, was a significant factor in the exceptional performance and success of the project. In fact, the team made it a priority to minimize personnel radiological exposure (ALARA) and incorporate industrial safety into the tooling systems. Specially designed shielding for machining activities was developed, utilizing Tungsten-infused rubber to dramatically reduce dose. Use of this shielding arrangement required fewer lead-shielding blankets, which helped reduce trip hazards and created a more orderly work area.

A newly refurbished reactor coolant pump is prepared for shipment.

Use of an improved, shielded RCP shipping cask contributed significant benefits to the project. Upgraded based on lessons learned from previous pump outages, the improved design incorporated trunnions and a storage cradle in the shipping container itself, reducing the time needed to up-end and down-end the cask using the polar crane from 10 hours to two hours. This rigging arrangement was much simpler and reduced the risk of a rigging issue or human error associated with multiple hooks or cranes. It also has a smaller footprint, thus taking up less laydown space, which is valuable during a busy outage.

The project team also came up with numerous ways to successfully improve on



Personnel perform a specialty training to prepare for the Surry project. Workers are dressed out with PAPR hoods and suits, training on a mock-up for case machining.

process and equipment efficiency, ensuring the outage schedule was maintained and budget was met. For example:

- AREVA's FARO Arm metrology technique was used to obtain critical case diameters and the different dimensions of the pump components. This allowed for 3-D overlays of new and old pumps for possible deviations. This method was not only more accurate than manual measurements, but it was also much faster. Digital indicators, in place of standard dial, were used so machinists could quickly and accurately read the measurements. This was quicker and kept the workers away from the dose source.
- Flow curves, piping configurations and thermal monitoring systems were some of the challenges that had to be worked through to fit a different style pump from one plant to another. Dominion worked with AREVA to fabricate new shafts and impellers for the pumps to achieve flow requirements and extend plant life with new pump components and upgraded hardware.
- Using the best available remote video monitoring and communication equipment helped reduce time and dose by getting answers straight from the field to the project team, and eliminated multiple oversight personnel by using video monitoring and inspection.

Using these new processes and equipment allowed for a reduced critical path schedule, eliminating the up to seven-day outage extension required for RCP replacements in the past. In fact, this project proved that multiple RCP replacements are possible during a normal maintenance outage.

Looking Forward

IGSCC in RCP TV bolts is one of the most important reasons for replacement and refurbishment of RCPs in the U.S. nuclear fleet. A growing number of operators will need to consider RCP replacement as these components continue to age.

The proven, systematic approach to replacement and repair for RCPs used at Surry units 1 and 2, including lessons learned and improved equipment and processes, can help to greatly improve the reliability of all nuclear facilities across the United States.

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William Murray

William (Will) Murray is a consulting engineer at Surry Power Station. Will holds an Associate's Degree in manufacturing engineering and a Bachelor's Degree in mechanical engineering, and is a licensed Professional Engineer in the state of Virginia. Will has more than 35 years in the nuclear industry, including 30 years at Dominion. Twenty-five of the years with Dominion have been at Surry Power Station in Design, Components and Project Engineering.

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