TRENDS IN NUCLEAR INSTRUMENTATION AND CONTROL SYSTEMS 2021

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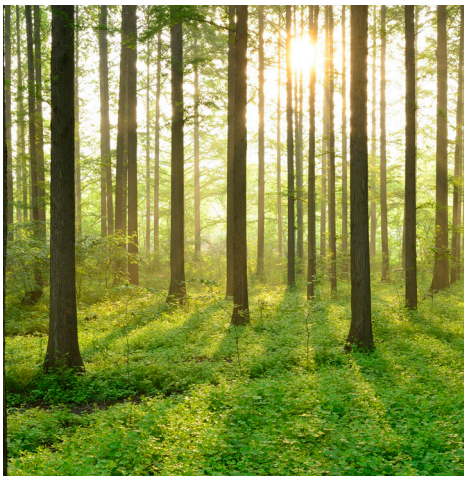

NUCLEAR

ENERGIFORSK NUCLEAR SAFETY RELATED I&C – ENSRIC

Energiforsk

Trends In Nuclear Instrumentation and Control Systems 2021

Report from ANS. conference NPIC & HMIT 2021

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Foreword

U.S. conference NPIC & HMIT is one of the larger conferences covering the nuclear instrumentation and control area. Covering this conference is an efficient way of picking up international trends and tendencies.

The conference was covered by senior expert Emil Ohlson from Forsmarks Kraftgrupp AB. This project is included in the Energiforsk Nuclear Safety Related Instrumentation and Control program – ENSRIC. The project is financed by Vattenfall, Sydkraft Nuclear/Uniper, Teollisuuden Voima Oy (TVO), Fortum, Skellefteå Kraft and Karlstads Energi.

Summary

This report summarizes impressions and reflections from a major I&C and HMI conference organized by the American Nuclear Society. This year the conference was completely digital and was broadcasted via Zoom.

Characteristic themes for the conference were the design and development of advanced reactors, cyber security in nuclear power plants and the innovative use of new technologies that are beginning to enter nuclear power plants around the world, such as wireless networks, drones and machine learning systems.

Keywords

Nuclear, I&C, Advanced reactors, Cyber Security, ANS, Innovation

Kärnkraft, I&C, Avancerade reaktorer, cybersäkerhet, ANS, Innovation

Sammanfattning

Denna rapport sammanfattar intryck och reflektioner efter en större I&C och MMI konferens anordnad av Amerikan Nuclear Society. Konferensen var detta år helt digital och sändes via Zoom.

Utmärkande teman för konferensen var design och utveckling av avancerade reaktorer, cybersäkerhet inom kärnkraft samt det innovativa användandet av nya tekniker som börjar inträda i kärnkraftsanläggningar runt om i världen, såsom trådlösa närverk, drönare och system med maskininlärning

List of content

1 Abbreviations

ANS	*American Nuclear Society*
CCF	*Common Cause Failure*
CGD / CGID	*Commercial Grade Dedication / Commercial Grade Item Dedication* Use of products not developed according to nuclear power criterions for safety applications. The utilization can be motivated by simulation programs, analyses, operational data or, most commonly, a combination.
COGS	*COTS Goal Based Self Assessment* A ”claim-based” method used to justify COTS products.
COTS	*Commercial-Off-The-Shelf* Soft- or hardware which can be bought or licensed from an open market contrary to custom made solutions.
DDoS	*Distributed Denial of Service*
DI&C	*Digital Instrumentation & Control*
EMC	*Electromagnetic Compatibility*
EPRI	*Electric Power Research Institute*
FPGA	*Field Programmable Gate Array*
I&C	*Instrumentation & Control*
IAEA	*International Atomic Energy Agency*
IEC	*International Electrotechnical Commission* – A standards and conformity assessment body within Electrical and I&C
LPRM	*Local Power Range Monitoring* A system to locally measure neutron flux within the reactor core. Several LPRM are typically used to form Average Power Range Monitoring (APRM).
MMI / HMI	*Man Machine Interface* / *Human Machine Interface*– The interface between operator and the process facility.
NPP	*Nuclear Power Plant*
PLC	*Programmable Logic Controller*
SSPS	*Solid State Protection System*
US NRC / NRC	*United States Nuclear Regulatory Commission*
V&V	*Verification & Validation*

2 Introduction

This report is a conference report from a major conference in the Instrumentation & Control (I&C) and Human-Machine Interface (MMI / HMI).

The report aims to reproduce the trends, presentations and reflections that the author perceived during the conference. The content does not reflect everything presented at the conference, rather it is limited to the sessions that the author could attend, as well as some areas where only the topic reports could be read (where it was not possible to attend this session).

The task to observe and report from the conference was given by Energiforsk to Emil Ohlson, Forsmarks Kraftgrupp AB.

3 Conference

3.1 GENERAL

During week 24 in 2021, a major conference concerning I&C and HMI within nuclear power was held, this time for the first time as a virtual event due to the ongoing pandemic. The organizing unit was the ANS (American Nuclear Society) and the conference is a recurring event in which different areas of focus are addressed. This year's conference was the 12th in this topic.

The conference was an Embedded Topical Meeting to ANS Major Annual Meeting 2021, which deals with nuclear power at large and addresses much more areas than just I&C and HMI.

Each conference usually has a slogan that reflects the location, situation and mood for both the actual meeting and the industry as a whole. As this year's conference was a virtual one, there were not much of a location aspect to take into consideration. The slogan for this year's conference was "Breaking Through to Deployment", where Deployment in this case means the deployment and evolution of Advanced Reactors including Small Modular Reactors (SMR) and Micro Reactors that is currently in progress.

ANS is an international non-profit organization for research, education and organization in nuclear power. It was formed in 1954 and today has about 10,000 members from more than 40 countries (most from USA) representing over 1,600 companies, research institutes, universities and government agencies. The purpose of the organization is to work for understanding and knowledge in nuclear power technology. For more information on ANS different divisions, see www.ans.org or more specifically www.new.ans.org/about/committees/

ANS conferences are usually divided into two different ways; It is either a larger meeting with several different technology areas involved (e.g. I&C, Materials Technology, Calculation Program, etc.) or only one area represented. This year's conference was of the large sort and comprised both nuclear power in general and specifically I&C and HMI.

The NPIC & HMIT conference was divided into two main tracks - I&C and HMI, which in turn were divided into several different technical areas. This meant that there were always up to six presentations and sessions that took place in parallel at the NPIC & HMIT meeting, along with the additional up to ten parallel sessions from the ANS Annual Meeting. This meant a lot of planning to participate in the sessions and presentations that were considered relevant and interesting to one's own.

Previous years there has always been a larger exhibition going on where vendors and companies within the nuclear area showed new technologies and equipment invited to dialog and technical discussions. This year the exhibitions was virtual. This meant that you could book a visiting time for a virtual visit and discussion with the staff at the different vendors and exhibitioners. The exhibition was in parallel with the conference during most of the week but for natural reasons the

number of exhibitioners was smaller this year. Only 7 companies were present as compared to a normal year with over 20 exhibitioners.

During the weekend before the meeting, two virtual one-day training courses was also organized and addressed different topics related to nuclear I&C and HMI.

These workshops where led by engineers and experts from the different companies or laboratories at the conference and is aimed to provide a deeper knowledge and understanding within different areas.

Approximately 1600 people representing different organizations and companies from around the world attended the ANS conference. As the NPIC&HMIT was part of the ANS meeting and registrations were made to the larger ANS Annual Meeting also for participants to the NPIC&HMIT meeting, there is no attendee number for the NPIC&HMIT meeting but a rough guess -based on the number of participants at the sessions and number of papers admitted- is the approximately 300-400 people attended the NPIC&HMIT parts.

This year, a larger part of the presentations was from National Labs or research institutes than a “normal” year, and there were fewer presentations from vendors and utilities. The reason is believed to be related to the pandemic and the virtual conference, as many vendors and utilities attend such conferences for the possibility to meet and interact with peers and other utilities, and that possibility is largely limited in a virtual meeting.

In total, about 150 reports (so-called "papers", meaning a shorter summary reports) were sent to the NPIC & HMIT conference, and about an additional 200 at the larger annual general ANS conference. This makes the number of papers and sessions slightly smaller than what would have been expected a “normal” year.

During the week I was able to listen to 58 different technical presentations, overall lectures and panel discussions.

The conference with all presentations, panels and plenary sessions is seen as a very good opportunity to get a hint of what is going on within the industry.

3.2 CONTENT

As mentioned, the NPIC&HMIT part of the conference was divided into two main tracks – I&C and HMI, and under these main areas there were technical sessions with presentations and panel discussions according to the list below. Certain sessions are quite extensive and are therefore divided into different rounds (one round equals the morning or the afternoon).

In the morning prior to the first regular technical session, there were also so-called Plenary Sessions and Special Sessions, these sessions were hosted by the ANS Annual Meeting and continued as long as the ANS Annual Meeting. The speakers at the Plenary and Special sessions were often handpicked to address a certain topic or issue and was often people who had high positions in the industry (e.g. CEOs from different companies, people from the Department of Energy, Commissioners from NRC mm). Normally, these sessions comprised of a short presentation from each session member followed by a panel discussion and

questions from the audience. As this was a virtual meeting some of these presentations was pre-recorded in order to have someone presenting that did not have the ability to attend the very moment (e.g. Jennifer M. Granholm, the Secretary of the U.S. Department of Energy gave a presentation by pre-recorded video).

Each technical session then contains between 3-20 presentations. The different sessions at the conference were (without relevant order but divided into the different "tracks"):

- Human Machine Interface Technology
    - Advances in Control Room Design
    - Advances in Human Factors and Human-Automation
    - Enabling VERA Software Support for Reactor Diagnostics and Aging Management – Panel
    - Panel Discussion on I&C and Human Factors Standards – Panel
    - Real-Time Demonstration of the NuScale Control Room Simulator – Panel
    - Latest Trends in Human Factors
    - Modernization Strategies for the Main Control Room – Panel
    - General Topics in Human Factors and Human-Machine Interface
- Nuclear Power Instrumentation & Control
    - OLM Implementation for Surveillance Frequency Extensions - Panel
    - Advances in Sensors and Sensor Characterization
    - In-Pile Instrumentation
    - New Developments in EMC / Wireless Implementation in Equipment and Process Condition Monitoring, Diagnostics, and Prognostics - Panel
    - Application and Research into the Use of EDDs
    - Regulatory Applications and Guidance for the Use of EDDs
    - Digital Twins
    - Advances in Instrumentation and Controls Systems
    - Safety Critical Software Development, Qualification, and V&V
    - Advanced Surveillance, Diagnostics, and Prognostics
    - Maintenance Planning and Optimization
    - Latest Trends in Digital Instrumentation and Controls

  - Transformational Challenge Reactor (TCR) - Transforming the Paradigm of Instrumentation and Controls for Future Nuclear Systems - Panel
  - Harsh Environment Electronics For Terrestrial Reactor Applications: Needs, Technologies, and Future Directions - Panel
  - Cybersecurity in Nuclear Installations – I-III
  - Data Analytics, Machine Learning, and Artificial Intelligence – I-III
  - Digital Considerations for Safety Applications
  - General Sessions in I&C
  - Productivity/Efficiency Improvement
  - Instrumentation and Controls Regulations, Standards, and Guidelines
  - Instrumentation to Support Monitoring and Situational Awareness
  - Advanced Sensors and Measurement Technologies
  - Beyond Piecemeal Plant Modernization - The Digital Challenge for Total Plant Transformation - Panel
  - Electromagnetic Compatibility and Wireless Technology
  - I&C for Autonomous Operations and Online Maintenance in the Next Generation of Reactors - Panel
  - Safety-Related Applications of Advanced I&C
  - Cybersecurity Simulation, Testbeds, and Experiments
  - Digital I&C Modeling Approaches for PSA
  - I&C Technologies for Space Reactors and Microreactors
  - Autonomous Control and Operation
  - Addressing Common Cause Failure and Future Regulatory Challenges - Panel

- ANS Annual Meeting (sub-divided into ANS Divisions) *[Note that these sessions are not covered by this report, only included as information about the ANS meeting content]*
  - Education, Training & Workforce Development Division (ETWDD)
    - Crisis Communications During Emergencies in the Social Media Era – Panel
    - Choosing Panelists with Diversity, Equity and Inclusion in Mind – Panel

        - ANS Nuclear Grand Challenges
        - Operationalizing Diversity, Equity, and Inclusion (DEI) Statements within the Nuclear Field – Panel
        - Young Nuclear Engineering Programs: New, Embedded or Hybrid
    - Executive Panels
        - Per Nuclear Ad Astra - The Future of Space Nuclear Technologies - Panel
        - Polar Vortex 2021: Lessons from Texas and the Central U.S. - Panel
        - The U.S. Nuclear R&D Imperative - Panel
        - Crisis Communications During Emergencies in the Social Media Era - Panel
        - Planning for the Future: Demonstrating Next-Generation Nuclear Capabilities with Non-Power Technologies - Panel
        - Near Term Action on Nuclear Waste - Panel
        - Operationalizing Diversity, Equity, and Inclusion (DEI) Statements within the Nuclear Field - Panel
        - Blind Spots to Implementing Lessons Learned for New Nuclear Construction – Panel
    - Fuel Cycle & Waste Management Division (FCWMD)
        - Used Fuel Storage and Transportation
        - Molten Salt Reactor Chemistry and Analysis
        - Fuel Cycle Needs to Support Advanced and Small Reactors - Panel
        - Advances in Recycling of Used Nuclear Fuel
        - Closing the Fuel Cycle with Small Modular Reprocessing Facilities - Panel
        - Safeguards and Security By Design: The MPACT 2020 Milestone - Panel
        - University Research in Fuel Cycle and Waste Management
        - Fuel Cycle and Waste Management: General
    - Isotopes & Radiation Division (IRD)
        - Radiation Detection for Homeland Security

        - Isotopes and Radiation: General
        - Highlights from the 2020 Workshop on Accelerated Irradiation for Reactor Structural Materials
    - Mathematics & Computation Division (MCD)
        - Current Issues in Computational Methods – Roundtable - Panel
        - Transport Methods
        - Computational Methods and Mathematical Modeling
    - Materials Science & Technology Division (MSTD)
        - Fuels and Materials for Molten Salt Reactors
        - Accident Tolerant Fuels and In-Pile Testing
        - Post-Irradiation Examination and In-Pile Instrumentation
        - Nuclear Science User Facilities – I-II
        - Nuclear Fuels and Materials
    - Nuclear Criticality Safety Division (NCSD)
        - Sharing of Good Industry Practices and/or Lessons Learned in Nuclear Criticality Safety - Panel
        - Data, Analysis, and Operations in Nuclear Criticality Safety – I-III
        - Education in Criticality Evaluation and Reactor Physics - Panel
        - NCS Qualification at Different Sites - Panel
        - ANS 8 Standards Forum
    - Nuclear Installations Safety (NISD)
        - Technical Issues Faced in the Non-LWR Probabilistic Risk Assessment Standard Development - Panel
        - Nuclear Installations Safety: General
        - Current Topics in Probabilistic Risk Analysis
        - Risk-Informed-Performance-Based Approaches to Design for External Hazards for Advanced Non-LWRs - Panel
    - Nuclear Nonproliferation Policy Division (NNPD)
        - Radiation Detection for Homeland Security

        - Technology and Policy Advancements in Nuclear Nonproliferation
        - Safeguards and Security By Design: The MPACT 2020 Milestone – Panel
    - Operations & Power Division (OPD)
        - NS Savannah History - Panel
        - Walter Zinn Medal Special Session: Honoring Dr. José Reyes
        - Operations and Power: General
        - Advanced Nuclear Reactors and Power Systems
        - Modeling and Experiment Capabilities to Support MicroReactor Development - Panel
        - Hybrid and Integrated Energy Systems
        - History of Non-Naval Nuclear Ship Power - Panel
        - Microreactors: Technology Readiness and Market Opportunities – Panel
    - Reactor Physics Division (RPD)
        - Reactor Physics: General – I-II
        - Reactor Analysis Methods – I-II
        - Machine Learning and Artificial Intelligence in Reactor Physics and Design - Panel
        - Physics of Compact Reactors for Terrestrial and Space Applications
        - Education in Criticality Evaluation and Reactor Physics - Panel
        - Thermal Hydraulics Research in VTR and TCR Programs
        - Versatile Test Reactor - Current Developments - Panel
        - Reactor Physics Design, Validation and Operational Experience
        - Reactor Physics of Advanced Reactors – I-II
    - Radiation Protection & Shielding Division (RPSD)
        - Radiation Detection for Homeland Security
        - Radiation Protection and Shielding: General

        - Computational Methods in Radiation Protection and Shielding
        - CAD-to-Transport for Radiation Protection and Shielding
    - Thermal Hydraulics Division (THD)
        - General Thermal Hydraulics and Heat Transfer Fundamentals
        - Challenges and Opportunities in Thermal Hydraulics of Load-Following Nuclear Systems - Panel
        - Thermal Hydraulics Research in ARPA-E Programs - Panel
        - Thermal Hydraulics Research in VTR and TCR Programs
        - Thermal Hydraulic R&D Activities in Printed-Circuit Steam Generators for Advanced Nuclear Reactors
        - Thermal Hydraulics for Advanced Reactors
        - Experimental Thermal Hydraulics
        - Computational Thermal Hydraulics – I-III
    - Young Members Group (YMG)
        - Acing the Interview Workshop - Panel
        - Running for Public Office: Why STEM Professionals Should and How to Get Started - Panel
        - Choosing Panelists with Diversity, Equity and Inclusion in Mind - Panel

Sessions with "I-III" after the title indicates that this session was divided into several round (3 rounds if "I-III" is indicated).

As can be seen from the list above, the Instrumentation and Controls Division was the division with far most presentations, and the Human Factors Division was one of the biggest. A contributing fact is most likely that there was a topical meeting on I&C and HMI, but nevertheless, I&C is one of the biggest areas within nuclear power.

Also noticeable from the list of sessions above is that Data Analytics is a big topic not only within I&C but also within other areas and divisions such as the Nuclear Criticality Safety Division.

4 Larger topics and trends

This chapter contains a collection of topics and areas that either covered several rounds and thereby many presentations, or topics that were smaller but still significant in its content, or was mentioned a lot during sessions, panels and plenary's.

4.1 BEING COMPETITIVE AND ENVIRONMENTLY FRIENDLY

A lot of the discussions and panels during the meeting addressed the challenge for nuclear with being competitive on a more complex market, and with other prerequisites compared to when today's NPPs were built. Some energy types such as wind and solar has for example no fuel cost and are also always prioritized on the grid when in operation, and hence, are not so affected by longer low-price periods.

And the large competition for nuclear from gas, wind, solar etc. and low prices has resulted in NPPs being shut down before their technical EOL due to financial reasons. But since the nuclear is a large part of USA CO2 free energy, many has come to the conclusion that for USA to keep their CO2 goal (President Biden has declared that the electricity productions shall be CO2 free by 2035, and net zero emissions economy-wide by no later than 2050), nuclear must be a part of the equation. And since the prospect of building many new large nuclear reactors in the USA is very unlikely, the solution is rather to keep the existing reactors in operation. As a consequence of this, some NPP that was planning to shut down due to financial reasons has been given support from the state who wanted to keep the NPP due to environmental reasons.

The Secretary of the U.S. Department of Energy, Jennifer M. Granholm, said in her plenary talk that the DoE had three priorities regarding nuclear:

1. Focus on keeping the existing reactors in operation
2. Find a solution for the final depository
3. Advanced Reactors and SMR

Some numbers that were presented as a goal for reaching a competitive level was to have 0,5 FTE / MW.

Something that was mentioned a lot was "Clean Energy Jobs", meaning that when looking at the energy market and production, one shall not only consider the CO2 emissions, but also look at how USA creates job opportunities within the energy sector. The Biden administration seems to have given extra attention to this statement; that the solution for the energy business shall include both low emissions and high employment. Clay Sell who is the CEO on X-Energy also addressed this by pointing out that nuclear provides long standing jobs for many years to come, versus wind and solar that do not provide almost any jobs at all once it is installed. Not requiring much labor to operate is of course attractive for

the energy company, but on a national level considerations must be made on the job front says Clay Sell.

Michael Shellenberger who is the President of Environmental Progress showed comparisons between different countries, regions and years with regards to CO2 emissions, prices for electricity and different power generation. He showed statistics that blackouts are more common, and often stays longer in areas with a high amount of wind and solar. Shellenberger also said that the electricity prices in California has gone up 7 times more than compared to other parts of the country, and that this difference is due to the large amount of solar and wind installed in California at the same time as they have been closing down nuclear. The same results can also be seen when comparing the price history for France and Germany since Germany took the "Energiwende" initiative.

As many parts of the world is ascending from poverty, the need and consumption of electrical energy is rapidly increasing in these parts, making for larger emissions of CO2 and other greenhouse gases. And the growing need for energy cannot be met solely by renewables in these cases (e.g. as that would render a very weather dependent grind), but rather coal and gas are the most common sources of energy, and thus increasing the emissions quite significantly. Had these regions relied on nuclear power, the emissions had been more or less unchanged even with the increasing demand according to Shellenberger.

Shellenberger also claims that much of the information that is being feed to the public today about energy and environment to a large extent is misleading and even false in some cases. Many times, these new installations (wind, solar with gas/coal backup) forces nuclear to close down for financial reasons. Sadly, this many times adds up to the region emissions to increase when they aimed at doing something positive for the environment. Shellenberger also says that people and politics want to do the right thing, but many times it is hard to realize just what the right thing is due to the large amount of misleading and sometimes incomplete information about the environment and the impact from energy production.

Michael Shellenberger points out that when looking at the energy solution it should be obvious that you need to consider the most energy-dense fuel as the most appropriate, just looking at the land area that would be needed to replace nuclear with wind and solar makes it impossible to do in most populated areas of the world.

During one of the plenary sessions, it was also expressed that many politicians and companies do what they know is popular with public, rather than what they know is right for the environment, something that unfortunately is seen in other areas as well. It sometimes seems more prioritized for politicians to stay in office next election period, and for companies to make profit, than to take the necessary -but not always the most popular, decisions.

The use of batteries in the grid to balance wind and solar was discussed. It was seen as an interesting small-scale solution, but nothing that could replace existing plants. The capacity for these batteries is quite low and the ability to provide electricity in any larger scale was believed unrealistic. According to some calculations, if all grid battery plans go well, by 2040 the USA grid will have a

capacity to provide electricity from grid batteries for 20 minutes if all wind and solar production stops. And as of today, there are days in a row with almost no wind and solar production every year.

During the CEO panel a remark was made about the new types of data centers (Facebook, Amazon, etc.) that are being built in many locations. These centers consume a lot of electrical power, and also need the power to very reliable, making NPP (also such as SMR or microreactors) the perfect choice for these centers. But often they want to market the new data center as "Powered by Green Energy" and builds lots of wind and solar at the same time. This makes for a double problem for the grid, since the power added to the grid (wind solar) actually pushes out the type of power needed by the data center (NPP).

Mark P. Mills, Senior Fellow of the Manhattan Institute Faculty said that the "Solar and Wind Revolution" is somewhat overrated if you look at it globally. Sure, many companies and countries in the west builds a lot of wind and solar, but if you look globally, wind and solar only counts for a few percentages of the worlds energy. Mark also presented numbers for electrical cars, the amount of electrical cars has gone up enormously the last 10 years, and is expected to reach 200-300 million electrical cars by 2030. But once again, if you look at it from a global perspective, even this large expansion would not decrease the amount of oil consumption very much. The figures Mark presented showed that 1000% increase of electrical cars would render a decrease of oil consumption by only 5% worldwide. And that making batteries for electrical cars if a quite large source of CO2 emissions (mining etc.), so that dependent on the electricity mix in the country where the cars is being used, an electrical car can actually have a larger CO2 footprint then a diesel car if you look at the lifecycle CO2 emissions. And one of the worst countries in this comparison was actually Germany.

The CEO panel also discussed around the fact that SMR and Microreactors will take a new role in the energy landscape than the existing reactors have had. Due to the fact the many energy need arises fast, and sometimes in somewhat remote places, one of the key factors for success for new nuclear will be the ability to be "soon deployable", compared to a Gigawatt (GW) reactor that many times take 10-20 years to build. New nuclear must have "a balance between short term action and long term thinking". Smaller reactors will also be better suited to perform load following than larger reactors and can thereby easier co-exist in the new energy market.

Cody Walker from Idaho National Laboratory said that there has been a sort of paradox these latest years. As most NPPs have invested billions of dollars to upgrade safety to be able to keep operations ongoing and not being shut down due to public opinion saying that the NPP is not safe, these upgrades increased the production cost and now causes the plants to not being competitive. All NPPs that are closing down right now do so due to financial reasons, and none due to lack of safety. Cody says: "Nuclear has never been safer, and at the same time, never so uncertain to keep operating".

During both the Presidents Panel and the CEO Plenary it was said several times that the most important for the environment and the energy sector was to keep the

existing fleet operating. It provides base load power that allows intermittent renewables, and it is an existing and real solution already today, as compared to advanced reactors that might be able to fill the gap in several years.

Just how dependent we have become of electricity was evident during the presentation from Rita Baranwal from EPRI. Her house experienced a black out that day, and although she had battery power to her laptop, when the power went out, so did her Wi-Fi. Rita was then forced to go to a local café that had both power and Wi-Fi, which showed that we all need clean and reliable power more today than ever before, and it is likely to stay that way for a very long period of time.

4.2 SHIFT OF POWER

One thing mentioned several times during the Opening Plenary's and special sessions was that USA needs to be the global leader of advanced reactors and SMR´s. For some years ago, the aim was to retake USA´s position as global leader within nuclear generation, but at this meeting the tone was a bit different. Currently, Russia and China builds and sells large Gen 3 GW reactors both domestically and internationally. This has given Russia and China a pole position considering Gen 3 reactors, and both Russia and China have proven that they can construct and build Gen 3 reactors to a reasonable price and timetable, something that US (and European) companies have not been able to show. One should though consider the US (and European) problems with building new nuclear at a reasonable price and time has been most predominant within the USA and western European markets, and the Russian and Chinese has mostly been operating outside these markets. The US built reactors have also faced a hard time competing against the Chinese and Russian reactors in the markets outside the US and western European markets, for example in Finland and around eastern Europe (e.g. Hungary, Belarus and Turkey has contracts and plans for Russian built reactors).

The feeling was however that US believes that they will not be able to retake this head start within the Gen 3 market, and the odds for building US designed large Gen 2-3 reactors are slim. The existing competence in the USA for large reactors and current technology are to a large part close to retirement, and without any new builds it will be very hard to build new competence. And therefore, the focus turns towards SMR and Advanced Reactors, were it is still believed to be possible for USA to take the lead.

This was even somewhat evident when listening to the presentations from the National Laboratories, were many seemed to be more focused in SMR and Advanced Reactors than what was the case some years ago. This was also stressed by the plenary presentation by the Secretary of the U.S. Department of Energy Jennifer M. Granholm who told that USA is putting a lot of funding into research on Advanced Reactors.

But what this will mean for the future is a bit uncertain. There will still be a large existing fleet with large reactors in operation in the USA, and questions regarding safety, maintenance and operations will still be valid. But since more of the competence on the latest technology and development for these reactors will be

outside USA, it is likely that within some years organizations such as ANS will be even more focused on SMR and Advanced Reactors, and the discussions around large reactors of today will be around maintenance, operations, being competitive on the new market and on decommissioning issues.

One other aspect of this was brought up by Clay Sell, CEO of X Energy; when USA is now longer the leader in nuclear technology, this will be a matter of national security since keeping the existing NPP fleet without (or with lesser) support from USA based suppliers and vendors will mean that within some years Russian and Chinese contractors and vendors could have a large part of the component market and be conducting modernizations within the USA NPP fleet. Something that potentially could have an effect on national security, and hence it should be a national interest on government level to keep the nuclear competence and vendors in USA.

4.3 CYBER SECURITY

Cyber security has been a large topic at the conference since digital I&C started to be discussed for safety applications, that means for the last 10-15 or so years. This year was no exception, and with 3 full sessions devoted to Cyber Security and one session for "Cybersecurity Simulation, Testbeds, and Experiments", it was clearly one of the biggest technical topics of this year's conference.

What was somewhat new this year was that many presentations discussed actual ideas and solutions on how to implement cyber security at a site, versus previous years when the focus has been more on standards and overall structure (often on a philosophical level) needed. This was seen as a good progress towards helping the NPPs with the issue, but still there is a bit further to go before the presentations get really "hands-on" and thereby provides aid for the NPPs.

Shannon Eggers from Idaho National Laboratory talked about something called Cyber-Informed Engineering (CIE), and showed a V&V model (Verification & Validation) for the cyber security aspect of a project. Shannon Eggers also suggested that cyber security should both be a part of the project but also treated a bit separate and with special attention, for example it was suggested that cyber security was assessed with a separate Cyber Security Risk Analysis at a very early stage of each project.

Shannon Eggers also pointed out that not many NPPs actually have a thorough and well updated plan for how to act in case of different cyber-attacks on different levels (Main Control Room, Admin network, etc.). She said that it would be important to have a Cyber-Attack Emergency Procedure in case of severe cyber-attacks, just like you have emergency procedures for most plant related events and accidents.

Ray Fasano from Sandia National Laboratory presented a concept called Defensive Computer Security Architecture (DCSA) that addressed that a good cyber security plan had two parts. First off was the Defensive in Depth (DiD) concept with different levels or layers where the inner layer only sends information to the outer layer but never receives any data (e.g. Data Diodes), this is very common and is

used at most facilities. Additional to this Ray Fasano meant that you also need a form of "ejection seat" similar to pilots in aircrafts, this means an emergency plan (or button) to be used when you realize that you are experiencing a cyber-attack and is about to risk losing control over some of your plant or equipment.

Ray Fasano also pointed out that many times attacks has shifted from Operation Phase (meaning plants in operation) to Design Phase (meaning vendors and suppliers, but also maintenance companies). Something that makes it harder for the sites as it could potentially install a compromised component in an inner security layer, making the DiD concept compromised. And that it is many times a difference when you categorize functions and components in classes important to Reactor Safety and important to Cyber Security. Many attackers would probably not be aiming at causing a nuclear accident with radiological release to the environment, but would rather be "satisfied" with causing failure and damage to larger Balance of Plant components such as transformers, generators etc. Such an attack could cause long standstills and enormous financial damage, but also have an effect of public opinion and regulation.

It has also been quite common with attacks where the attacker takes some part of the system "hostage" and locks it from access to the plant personal. Several cash machine systems in Sweden experienced a similar attack this summer (e.g. Coop). Just image the reactions on the headline "Nuclear Power Plant controlled by cyber terrorist" even if it "just" was the Balance of Plant equipment that was locked by cyber attackers.

Many plants and vendors see both financial and technical benefits with integrating many functions and systems into a centralized system. But although this can be positive in a financial aspect, it many times makes the system much more vulnerable for cyber-attacks, both since this means that more functions can be affected when attacking the central system, but also since very large centralized systems that can interact and communicate with many different systems tend to be much harder to test and verify.

As seen in many cases, cyber security is often a tradeoff between function/useability-security-economics. This aspect can also be seen in many modernization projects when vendors often don't have a function dedicated, nuclear grade system, but rather a versatile system that can be used in a number of applications and industries and is configured and modified to the attended application in the plant. This is good for financial reasons but bad for cyber security reasons.

Much work and effort are needed to fully manage the cyber security issue, both in terms of design and engineering hours and also testing and verifying, but also in terms of analysis and licensing related costs. When the analog systems were developed, none of these costs were relevant, and one can wonder how much cyber security actually is driving the costs in modern I&C projects.

The pandemic has also risen some new cyber security questions, with the large amount of distance working. As most NPPs have the majority of their non-operational staff working from home, they have granted access to many administrative networks and functions that was not accessible prior to the

pandemic. This has been a must in order to keep the work going and at the same time keep the spread of the corona virus as low as possible. But it also opens many new attack surfaces for cyber-attacks. And indications are that the distance working will continue at a high level even after the pandemic is over, and that every day there will be several legit off-site logins by employees to systems that has high cyber security importance, and therefore it will be harder to detect when a login to such a system is not legit but done by an outside party. This stresses the need for the NPPs to maintain a good cyber security structure and a high level of cyber security even when trying to make systems more usable for distance working.

4.4 USE OF DRONES

In the wake of wireless, data analytics and aim for cost savings, comes the use of drones. At the conference, several institutes and companies presented existing and upcoming drones that could be used within a NPP to carry out different tasks such as collecting data during rounds, conduct inspections on leaks or other issues.

Drones have been used in other applications than nuclear for quite some time and can for example be used to make a very precise 3D model of a structure or building with a photo surface. For example, the pyramids in Egypt have been modeled using drones equipped with 3D scanning and photo technique. The models were so exact and showed the pyramids from angles and ways seldom seen before, which led to new discoveries of the pyramids' construction and also allowed scientists from all over the world to make very precise studies of the pyramids from their living rooms using a laptop.

Jason Gasque from Tennessee Valley Authority (TVA) said that very much has happened in TVA the last 18 month regarding drones. They have gone from 2 to 35 drones, and now have 26 licensed drone pilots. TVA estimates that using drones for inspections has saved up to four million dollars for nuclear and hydro dam inspections, as compared to building scaffolding etc.. TVA also discusses to have drones for "standby" situations, where the drones are kept and charged in a type of box in location on site and can be deployed quickly if needed. Jason also says that since the cost for a drone is so low, it can be worth it for a drone to monitor a leak for instance even if the radiation is higher then what the drone can stand in the long run. The information it can provide is very useful, and the drone is very cheap and easy to replace if it fails.

Most of the drone examples showed and presented at the conference were drones that facilitated cameras, microphones and other sensors. Live video or data transfer allows the plant to remotely assess the area or equipment where the drone is located.

A common use of drones is for inspections in high radiation areas, where a drone can either replace humans for simple standard rounds data collection or provide a "first-impression" of a certain situation.

Drones comes in many shapes and sizes. Some examples used was flying drones with a "soft shield" around them in order not to cause any damage to plant

equipment should it collide during transport, other examples were drone vehicles which moves by tires and also expels of “Spot the Robot Dog” that walks around on four legs.

Different drones have off course their pros and cons for use in different areas and environments. Drones that move on the ground is hard to use in areas with stairs and different floor levels or if there are obstacles (e.g. pipes) on the floor or if the plant has sections of grid floors. Although walking drones (e.g Spot the Robot Dog) actually can maneuver in stairs in some cases. But flying drones has a larger risk of bumping into more sensitive equipment (e.g. transmitters) as that type of equipment is often placed higher up. Flying drones also has a risk of landing/crashing at an inappropriate location if -for example, communication or power fails.

Maneuver and navigation can also be carried out in different ways. The most common was navigation by remote access where a human remotely controls the drone. This require the use of some wireless commutation (Wi-Fi, radio etc.), something that could be an obstacle in some locations. Navigation by the use of GPS is also quite common, but for NPP with thick concrete walls this is not a suitable option. One other solution for navigation was presented by Ahmad Al Rashdan from Idaho National Laboratory that had a flying drone that navigated using camera and certain QR-codes that was placed on the walls, by scanning the different QR-codes the drone could calculate where it was and how to navigate. The drone then moved around the area and collected data from low energy wireless networks (only accessible just close to the sensor and therefore not interfering with other equipment) and then moved back to its dock and transferred the data through its base station that was connected to systems outside the room by wire. This provides a solution that is slightly less usable but still able to carry out the task without interfering with any plant equipment.

4.5 ADVANCES REACTORS AND SMALL REACTORS

The topic that got the most attention during plenaries and special sessions this year was Advanced Reactors. This is a quite large area, and in this abstract of presentations and comments, the term Advanced Reactors include Small Medium Reactors and Micro Reactors even if there are definitions elsewhere that says otherwise.

Some of the newer existing reactor designs such as AP1000 are sometimes referred to as an advanced reactor, but at the conference the main topic was smaller and less “conventional” reactors. There are many advanced reactors under design and development today, some examples can be:

- Molten Salt Reactor
- Fluoride Salt-cooled High Temperature Reactor
- Liquid Metal-cooled Fast Reactor
- High Temperature Gas Reactor
- Pebble Bed Reactor

- Nuclear Battery Reactor
- Lead Cooled Reactor
- Small Modular Reactors

One of the aspects of many advanced reactor designs is that they often have an additional output than just electricity such as hydrogen production, water desalination, process heat etc. This is one way to cope with the challenge that the existing NPP's have today in form of a tough market with fluctuating electricity demands and tough competition from renewables.

Per Peterson from University of California and Kairos Power told that the national think tank Third Way had made an assessment for the new nuclear development in USA and Canada and stated that more than 40 companies were developing plans for new nuclear plants in the USA and Canada. These companies were backed by more than $1.3 billion in private capital. And there are many private financiers for new advanced nuclear, Bill Gates being one example as one of the founders behind TerraPower who is currently developing a number of advanced reactor concepts such as Traveling Wave Reactor, Molten Salt Reactor and Sodium Fast (Natrium) Reactor.

Per Peterson also estimates that the design that Kairos Power is developing (Fluoride salt-cooled High Temperature reactor) will be cost compatible with natural gas. One reason for the cost being believed to be lower in an advanced reactor is that most designs have a very distinct boundary in the design and construction between nuclear and non-nuclear parts of the plant, making the non-nuclear side to be able to use vendors from all segments of the industry.

The advanced reactors have no Electrical or I&C part of their RPS, making them fully passive and independent of electrical power for safety purposes. And not only does this include a passive SCRAM system (that some reactor types have today) but also a passive function for Decay Heat Removal. This means that the I&C functions for advanced reactors are different from today, rather than Controlling and Activating, the I&C for advanced reactors focuses on measuring and collecting data (many times to be assessed by a Machine Learning / Big Data System). On the other hand, the designs many times requires the measuring and control of other sort and principles than regular NPPs, making the I&C equipment that is needed to many times be uniquely developed along with the reactor design.

Since advanced reactors are fully passive, and also many times can be built in such a way that would make it very inaccessible to terrorists, the needs and requirements for physical protection and security becomes significantly smaller for advanced reactors as compared to existing reactors.

The fact that many advanced reactor designs are "Low Pressure Designs" also make up for much lower requirements when it comes to mechanical integrity, making the mechanical engineering and construction significantly lower in cost. In some designs, the coolant itself has the possibility to prevent releases of radioactivity, so even if there would be a leak in a low-pressure system, the radiation exposure to third person would be neglectable.

Another concept mentioned a lot around advanced reactors was the concept of micro reactors. A micro reactor is a reactor in the range 1-20 MWt that is used as heat or converted to electric power. The micro reactors are very portable and can more or less be fully manufactured in the factory and transported to the site with as little as a couple of months construction work at the site needed from delivery of the rector itself to being operatable on the grid. It then requires very little maintenance and few operating staff and is inherently safe with passive safety functions. This feature makes it suitable for remote locations and e.g. military bases but it could also be used to power airplanes, trains, trucks etc. In many cases a micro reactor operates in very long operating cycles -over 10 years, and in some cases micro reactors never changes fuel but rather are loaded for End of Life operation already from startup.

There are also many examples where a site has an existing coal plant that has been shut down, or is about to shut down, and there is a proposal to replace the coal plant with an advanced reactor. As the larger electrical components such as generator, transformers are already on site, and also since the advanced reactors many times can be built using a small area, it is suitable to replace the coal plant with a new advanced reactor. Plans to do this was mentioned several times during the conference.

Although there were many that spoke positive about advanced reactors at the conference, and there are many benefits from the design that makes them an attractive technology, there are still some question marks that needs to be addressed. One question is the cost regarding licensing. Even if these are often smaller reactors in MW, the assessment for licensing cost and time is believed to be almost the same as for large reactors. And since it is many times a new technology and designs that somewhat differs from the conventional reactors, this is assessed to further complicate and delay the licensing process. The NRC says that they most likely will have to educate their staff in order to handle licensing of advanced reactors. Eric Brenner from the NRC said that the NRC need to define “What does safety really mean for advanced reactors?”.

One other issue with advanced reactors is that different designs are very diverse from each other. This is believed to make it more difficult to license, maintain and operate since it might be challenging to relate experience from one reactor design to another. This can also complicate things for the component vendors and companies that preform maintenance and outage/overhaul for NPP. The existing fleet of NPPs is quite streamlined and consist of mostly PWR and BWR, making up for a larger homogenous market for vendors and contractors. This is not believed to be the case of advanced reactors, something that might be an issue. Also, the existing reactors today, mostly use similar type of fuel (with the difference BWR vs PWR) rendering a market for nuclear fuel with different vendors competing, but advanced reactors use very different types of fuel, and the question was if making fuel to advanced reactors in a competing market could ever be achievable, and that the special (and also quite small) needs for both fuel and coolant for advanced reactors will end up being a problem. But then again, advanced reactors in most cases do not require that much maintenance or engineering after it has been put

into operation, and often very few (if any) refueling, so the diverse fleet might not be a big issue after all, and the future will have to tell what the outcome will be.

During the opening NPIC&HMIT plenary, the panelist discussed that, in some aspects advanced reactors has similar features as remotely controlled systems for space travel such as Mars Landers. The systems are more or less autonomous and needs to stay safe and operable during long periods without any interference from operators or engineers. The aspect of not needing reoccurring maintenance makes it possible to physically build it more or less as a bunker or in a way that makes it inherently secure from terrorist attacks or similar physical threats.

Even if the advanced reactors are a new technology, it still needs the old technology and the existing reactors. Jay Wileman, President and CEO of GE Hitachi Nuclear Energy says that if we close all existing nuclear power, there will be no competence and no public trust in the nuclear technology, and then there is no future for advanced reactors. So, keeping the existing reactors is a must in order to be able to build advanced reactors says Jay.

At one of the plenary sessions, a comparison was made between the aviation industry and the nuclear industry. The panelist said that the reason that the aviation industry works well in terms of logistics is that they have a mix of larger jumbo jets all the way down to smaller aircrafts for under 20 people. The different types of airplanes are then used according to the need for a particular route. You don't use a jumbo jet to take 30 people 500 km, and you don't use 25 small planes to take 500 passengers for long distances. And the same argument goes for nuclear, you should use large NPPs where there are large energy demands, and smaller SMR/Advanced Reactors where the demand is smaller. The panel pointed out that the advanced reactors are one piece of the puzzle and not a magic solution, we will still need large reactors with over 1000 MW output in many areas and applications.

Advanced reactors just might be a part of the future for the nuclear industry. But still, there is a general problem with developing expensive new technology. Or as Christopher T. Hanson from the NRC said during the opening plenary: "For new reactor technologies, it's a bit of a 'Chicken and egg' problem. Most technologies need a budget in order to become a reality. And in order to get a budget, they must first become a reality".

4.6 DATA ANALYTICS AND BIG DATA

The area of data analytics and computation was a somewhat larger area even this year. Many presenters saw it as completely normal to use different types of data analytics such as Machine Learning etc. in many applications. One thing that was relatively new this year was that many presentations recommended that instead of developing your own codes and algorithms, one should use already existing ones. Many applications developed for other industries could very well be used in the nuclear industry, but obviously not in the safety related systems.

Many presenters -mainly from the national labs, also said that there are many possible applications for the nuclear industry, but in order to take advantage of these, the industry must be more open to try new things and new ways. Some even

went so far as implying that if the nuclear industry did not open up, they would be outcompeted by other industries both in terms of cost efficiency and ability to attract people and personnel.

On-line monitoring and preventive maintenance is a large field within data analytics, and should also be an area where the NPPs can make cost savings. It is not always easy to make the right choice though. First off, postponing a scheduled maintenance just because the analytic system shows no indications that something must be changed of served, can cause a stand-still later on that will cost much more than the planned maintenance work. Also, there is the question on who decides the most appropriate parameter to monitor for a preventive maintenance program, and what the threshold should be? Compare with a car where for example the car manufacturer says one interval for changing oil and the oil manufacturer says another, and also the tire manufacturer recommends one tire air pressure and the car manufacturer says another.

One problem with data analytics and machine learning is that you need lots of relevant data to be able to make accurate predictions. Many times, the nuclear industry does not provide this data to the vendors due to cyber security reasons and the absence of means of communication (e.g. no wireless networks and very restricted means of communicating out from the sites for equipment -IoT). If comparing to vendors for airplane motors that has the same type of motor installed at several thousand airplanes, and they send diagnostic information to the manufacturer after each flight.

One comparison was made between the old General Motors cars and the modern Tesla. In the “old days”, GM got info from what parts in the cars that was more susceptible to ware then others first when the cars came in for service. And hence they had to first see the problem at service, then develop a contra measure and then install this at next service. Versus Tesla that sends information about each car every day, and when the time comes for service, not only does the technician know what is needed to change, the parts are pre-ordered and awaits at the garage when the car comes in. Also, Tesla has the possibility to develop solutions to unexpected problems much faster since they see the problem right away.

Seonaid Hume from the University of Strathclyde held a presentation about using wireless devises along with different data analytics systems for Automated Nuclear Waste Classification. Seonaid said that perhaps wireless and machine learning will be better suited to be used within waste and decommissioning, since that area is not a burden by the same old traditions and manners that yields from traditional nuclear industry.

As not many commercial NPPs are willing (or able by law) to test different machine learning algorithms and systems, more applications are developed for different research reactors and tested there. One example being the work that Jarod Wilson from Massachusetts Institute of Technology presented on “Development of an In-Pile Facility to Demonstrate Autonomous Control of a Subcritical System”. According to Jarod, the development was aided by the fact that MIT had both the test reactor and the development of the machine learning algorithms at the same University. The work was made more difficult by the pandemic though, forcing

Jarod to work from home and therefor build the test setup of the control rod automation system in his living room (luckily, he did not bring the reactor core home). Just one example of many on how work and research has been affected by the pandemic.

One reflection from many of the presentations regarding data analytics is that the technical development within this area outside of the nuclear industry goes extremely fast nowadays. Often a solution or a system can be outdated within a few years, and the vendor market in these areas many times won't provide service for older systems just a few years after it has been released. This is something that fits very poorly with the nuclear industry where deployment of new technology goes quite slow. The rate of technical development, and the ability for the nuclear industry to adapt to new technology is causing a gap, and this gap keeps growing bigger as the development advances. Also, the rate of the gap is increasing, and soon it might be too late to adapt. If the nuclear industry is to take advantage of the possibilities that follows this technology, the industry most likely must work in a different way. Some of the panels addressed this question and said that it was extremely important to be able to use these possible cost efficiencies in order to become competitive. Or as one panelist said "It´s a choice between adapting to the modern ways of new technology, or parish".

5 Other areas and conference notes

This chapter contains remarks and notes from presentations, panels or other sessions that is outside the scope of the larger areas presented in chapter four. They are reproduced without any order or priority.

- Digital Twins is something that is used more and more within the nuclear industry. Per Peterson from University of California and Kairos Power said that in the work with the Fluoride salt-cooled High Temperature reactor that Kairos Power is designing, they developed a digital twin early to test and challenge the system. As the reactor design is refined, so is the twin.
- Chad Kiger from AMS presented AMS's work on predicting component failures by measuring the radio emissions from that component. According to Chad, most components emit a different radio pattern as it degrades, making it possible to measure and predict when a component is degraded and about to fail. Something that could give the plant an early warning that a component needs attention. According to Chad, there are some real plant incidents that actually gave an EMC precursor and could have been avoided if the appropriate action had been taken in time. For example, a reactor trip in North Anna unit 2 had been preceded by excessive emissions caused by a failed capacitor, (the full list of events and precursors presented during the session). It is however easier to measure this when just looking at one isolated component then when it is installed in a cabinet and all the surrounding components interfere with the radio emission that is being evaluated. And many times, the plant radio "footprint" changes with operation, if for example a pump starts. It also requires very large amounts of data during many days to evaluate, both in Time and Frequency domain. Even so it is an interesting study that is in an early stage of the project, and it will be interesting to see how this will develop within a few years.
- Smitha Gautham from Virginia Commonwealth University presented a paper on Model-Based Design Assurance and Verification, something that can be used in design and engineering of safety systems. The method is somewhat based on the standard IEC 61508 – "Functional safety of electrical/electronic/programmable electronic safety-related systems". According to Smitha, these methods are already being used within the Aviation, Train, Car and Process Industry for safety applications. As most current NPPs are passed the design phase, this type of methods is believed to perhaps be used in the development of advanced reactors.
- Richard J. Stattel from the NRC talked about the challenge with applying a Single Failure Criterion to a digital control system, especially if you would take common mode software and logic errors into account. Traditionally, the Singular Failure would occur in one component and affecting one safety train, many times rendering the whole train out of function. This has been a very strain forward and logic operation, but if you look at a

software-based system, the Single Error could potentially be active in all trains, making the Single Failure transforming to a Common Cause Failure (CCF) affecting all trains. Both the NRC and the Licensees has problems with defining how to handle this question. Richard Stattel says that Digital I&C are more reliable and has better "self—monitoring" and error detection, making DI&C many times the preferred solution. But on the other hand, it is very hard to apply a Single Failure and still justify the system in a deterministic matter. Stattel rather recommends a risk based or risk informed approach when assessing DI&C for safety applications.

- Richard Hite from Virginia Commonwealth University said that there are two main reasons why the DI&C modernizations are costly; Regulatory/Licensing, and Verification and testing. The I&C in an NPP does not calculate very large amounts of data, and not at very fast speeds if you compare to many other applications. And most applications in an NPP are not very complex. Therefore, many times a NPP installs a DI&C system that has much more processing power and complexity then they actually need. If you compare to a modern car that has in the range of 100 million rows of source code. Richard claims that the plants could save large amounts of time and money on both of the main cost reasons if they used less complex systems or simpler FPGA systems. One example being the SymPLe system developed by Virginia Commonwealth University and being mentioned in an earlier NPIC&HMIT coverage report from Energiforsk.
- The NRC has produced a lot of documents and guides the latest years regarding licensing of digital systems and protection measures against CCF in digital systems. Eric Benner from the NRC said that one way to address the issue is to categorize all possible CCF into four different ways of dealing with the issue. Categorization is made by looking at the consequence and likelihood of each CCF. The categories are:
    - Eliminate
    - Limit
    - Mitigate
    - Accept
- Alexander Heifetz from Argonne National Laboratory (ANL) presented an alternative way for transmitting signals from one room to another but particularly through the reactor containment wall. Instead of using electrical wires, Alexander presented a method to use the existing piping that goes through the wall and send the signal by ultrasonic and millimeter waves in the pipe material. The focus is on high bitrate information, and in the test facility ANL has transmitted quite complex information and being able to decode it, for example, a digital high-resolution picture of ANL logotype has been transmitted and decoded. This could thereby be a way of sending signals through thick walls even

when there are no cables going through. The signal can be coded in order to prevent any unauthorized reading of the data.

- Kurt W. Derr from Idaho National Laboratory presented a paper on "Securing Wireless Technologies in Nuclear Facilities". Kurt said that you need to monitor the traffic on your wireless networks all the time in order to detect if something seems suspicious. INL has developed a system call WiFIRE that monitors the wireless traffic by several beacons around the plant. If WiFIRE detects a risk, it can give an alarm and tell what component is acting suspicious or even shut down the wireless network. The system can monitor both Wi-Fi and Bluetooth.

- Bill Ansley from Exelon talked about Exelon´s use of wireless in their plants. According to Bill, all NPPs within Exelon used wireless to some extent, mostly it was used to provide information for maintenance purposes. Bill said that one advantage with wireless was this it was COTS, and therefor much cheaper than most other equipment. And since it was COTS, it was also many times "open code" systems, so that the technicians and engineers could make their own applications or modify the existing applications in order to fit their need better. Bill presented projects that had gone from idea to implemented within weeks due to the fact that they used wireless (no need for cable installation) and COTS (can tailor applications themselves from their own need).
  Bill also stressed the fact that since there are so many different technologies and applications for wireless, when you are about to start using wireless for the first time, make sure that you have assessed your plant's particular need and prerequisites thoroughly, and make a wireless strategy for your entire need. Don't just rush in and start with something without thinking it through, since that many times will hinder you in the progress forward when you look at the next application.

- Olivia Chung from Ontario Power Generation touched upon the same topic as Bill Ansly in her presentation about wireless at OPG. She talked about the importance of having a "Management of Wireless Spectrum" even at an early stage, to handle infrastructural questions regarding wireless. Olivia also said that bandwidth could become an issue if you want to use lots of videos with high resolution, so you should try to predict your need for video and audio from the wireless network when setting up the infrastructure. Oliva said that OPG had experienced some problems with attitude and mentality from plant staff towards the use of wireless, and she recommended that you work in parallel with "soft questions" such as attitude when you do your first wireless project.

- Hrvoje Grganic from Framatome (he previously worked at the NPP Krsko) had looked at the failure rate and reported problems with wireless technology when used in the NPP. The result was far less problems than expected prior to installation. Hrvoje therefore wondered if we are making the potential problems and questions with wireless larger than they really are. According to the panel discussion at the wireless session, the panel was only aware of one incident where interference from wireless has

tripped a plant. And that was when a worker had brought his mobile phone into a radio-free zone, so the wireless should not be to blame in that case.

- During the opening plenary, the changing ways of operations for NPPs was discussed. It was agreed that "Base Load Operation" (100% power, 24/7) was going to change radically in the future. "We need to make nuclear a versatile part of the new flexible grid" was the statement. The nuclear industry must be able to provide both stable base load when needed, but also be able to lower production when needed and provide other types of services in that situation, and still be competitive. It was stated that in 2030-2040, when a lot of wind and solar will be installed, nuclear must have transformed into that versatile part, and be ready to meet the challenges -and opportunities, that will follow.

- At the Presidents Special Session, modelling was discussed, and specially models for making climate predictions. The models we have to make safety analysis in the nuclear industry are very well assessed and verified and have a high level of QA, still the results of theses models must be used with a high level of safety tolerance. But if you compare this to many climate models that are not as well verified, and many times developed by the same scientist that do the calculations and interprets the results. Major political decisions are made based upon the results of the (not so precise) climate models.
  We need three different, quality assured verifications, in order to decide if we reached 1195 C, or 1210 C core temperature, during a certain analyzed event, but we can make decisions that will affect future climate and thereby humanity, on the bases of a qualified guess.

- Richard Supler from Enercon Services talked about the issue with High altitude Electro Magnetic Pulse (HEMP), a question that was discussed in Swedish NPPs during the design of Independent Core Cooling System. A HEMP is a large discharge of electromagnetic radiation being set of at a high altitude. This can be produced by a single nuclear explosion detonated high in the atmosphere. A similar, smaller-scale EMP effect can be created using non-nuclear devices with powerful batteries or reactive chemicals, this is called High Power Microwave (HPM). There is also a similar phenomenon called Geomagnetic Disturbance or Geomagnetic Storm. The electric and magnetic fields that is generate by a HEMP can seriously damage plant electrical equipment and electronics.
  According to Richard, this type of incidents are believed to be able to cause the most damage to a nuclear facility, and they are categorized as Beyond Design Basis Events. A HEMP can be classified into three levels (E1-E3) with respect to discharge level and elapsed time, different equipment is sensitive to different levels (E1-E3). A HEMP from a nuclear detonation in the atmosphere would result in all three categories hitting the earth, first E1, then E2 and E3. Thereby the HEMP is able to cause damage in somewhat different ways and to many types of equipment.
  It seemed evident that a HEMP would do significant amount of damage if

it would happen. But the likeliness of this incident is very uncertain. Level E2 and E3 events can be caused by natural causes in space, but not the E1 level. The most dangerous HEMP, E1, requires substantial resources which no terrorist organizations are believed to be even close to having.
According to some sources though, both Russia and China are claiming to possess “Super HEMP Weapons”, something that could be a threat to US NPPs according to Richard Supler.
A report has showed that many industries and facilities have a week protection against HEMP, but Richard says that there are ways to mitigate the effect of such an incident.

TRENDS IN NUCLEAR INSTRUMENTATION AND CONTROL SYSTEMS 2021

This report summarizes impressions and reflections from a major I&C and HMI conference organized by the American Nuclear Society. This year the conference was completely digital and was broadcasted via Zoom.

The report highlights important trends or topics that were mentioned at the conference, as well as personal views on how these trends affect or could be of interest to the Nordic nuclear power plants.

Characteristic themes for the conference were the design and development of advanced reactors, cyber security in nuclear power plants and the innovative use of new technologies that are beginning to enter nuclear power plants around the world, such as wireless networks, drones and machine learning systems.

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