Application of Field Programmable Gate Arrays in Instrumentation and Control Systems of NPPs

A new IAEA publication

Janos Eiler

Lyon, France, 3 October 2016

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Outline

- IAEA activities in the area of NPP I&C engineering
- IAEA Nuclear Energy Series Document on:
  - “Application of Field Programmable Gate Arrays in Instrumentation and Control Systems of NPPs”

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Technical Working Group

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Technical Working Group on NPP I&C

Nuclear Power Engineering Section

Operating Reactors Support

- Plant Life Management for Safe Long Term Operation
- Instrumentation and Control Technologies
- Power Uprating in Nuclear Power Plants

Expanding Nuclear Power

- Electric Grid stability
- Nuclear Energy Human Resources Development
- Integrated Management System
- Strategic Support for Expansion of Nuclear Power

Scientific Secretary

Technical Working Group on Nuclear Power Plant I&C

- Hold the biannual general meeting
- Exchange technical & management information
- Identify & discuss issues of common interest
- Schedule and execute the work program

TWG website:
http://www.iaea.org/NuclearPower/Engineering/TWG/TWG-NPPCI/index.html

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Current members of TWG-NPPIC

- Argentina,
- Brazil
- Canada,
- China,
- Czech Republic,
- Finland,
- France,
- Germany,
- Hungary,
- India,
- Japan,
- Republic of Korea,
- Mexico,
- Pakistan,
- Russian Federation,
- Spain,
- Sweden,
- Switzerland,
- Ukraine,
- United Kingdom,
- United States of America
- International Organizations:
  - IEC TC45,
  - European Commission (JRC)

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TWG group photo from 2015

- The program for 2016 - 2019 was compiled in the last biennial meeting of the TWG in May 2015

Chairman of the TWG NPPIC

- Richard Wood of UT

French presentation in the TWG meeting

Priority list of recommendations from the 2015 TWG meeting

- I&C architectural approaches;
- Engineering and design aspects of computer security in NPP I&C systems;
- The application of wireless technologies in NPP I&C systems;
- Aging management of electrical equipment and components;
- Commercial dedication, application of COTS, type approval, product certification;
- I&C aspects of computerized operator support systems;
- Computer screen (VDU) based control room technologies;
- I&C support for process performance optimization;
- Application of different sets of codes, standards, and safety classifications;
- Support for newcomer countries and new NPPs.

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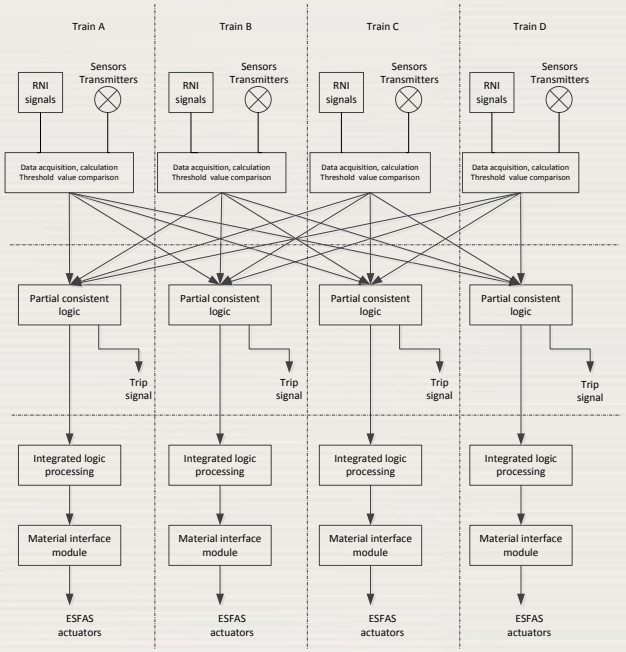
I&C architectural approaches

- Defense-in-depth
  - I&C functions for "Design Extension Conditions"
- Diversity
  - Justification of the required level of diversity
  - Diverse actuation system design
- Sustainability (ease-of-modernization)
- Security zones



- The application of diversity, independence and physical separation between different levels of the I&C system
- Design methods to resolve common-cause failure vulnerabilities

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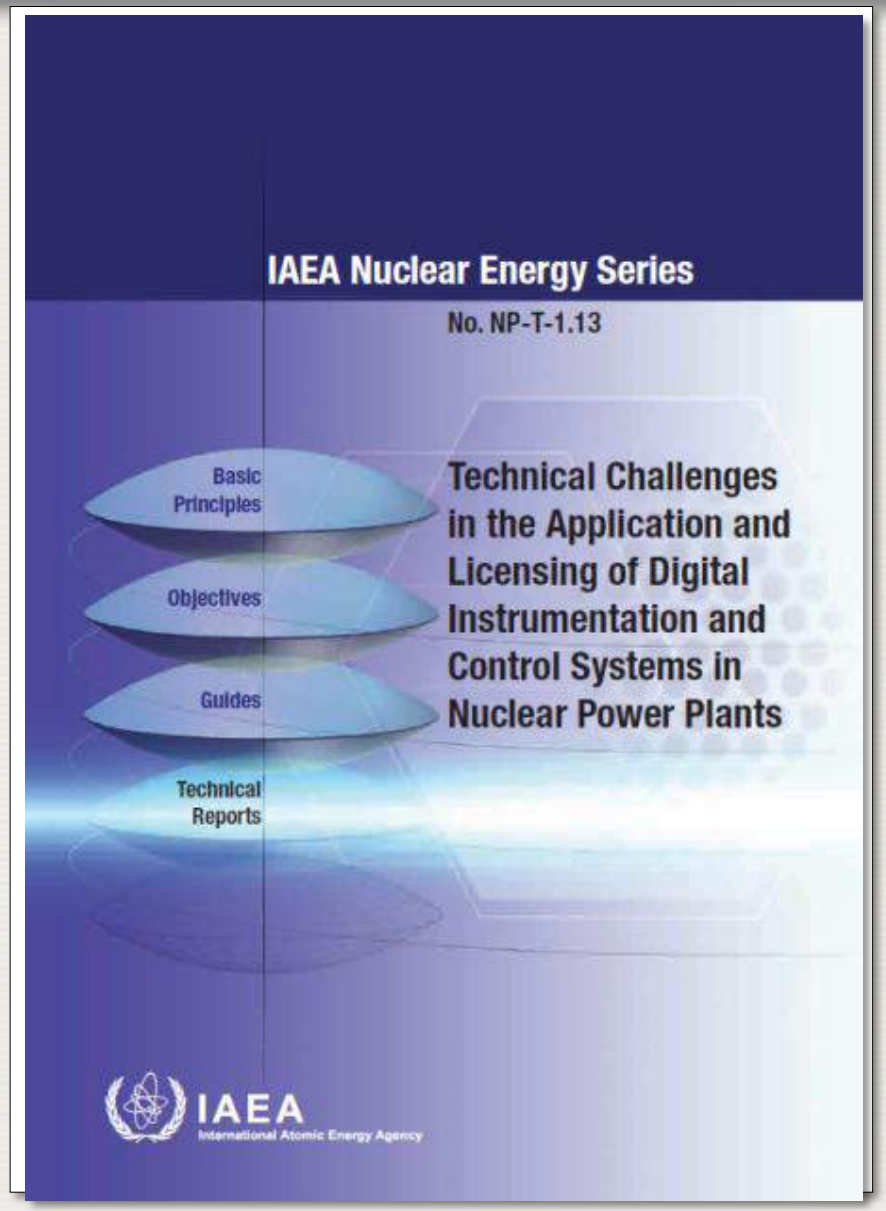
Harmonization of licensing practices

- Products accepted by regulators in one country are frequently difficult to obtain acceptance by another regulator
- Harmonization efforts are underway but progress is very slow
- IAEA TECDOC and new Nuclear Energy Series guidance



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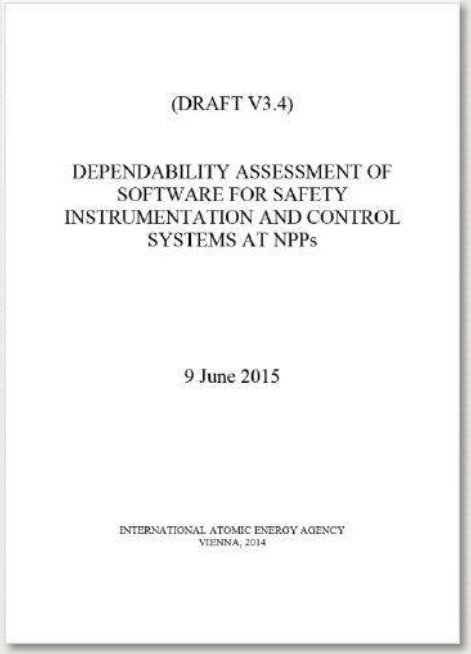
Issues with software dependability

- The evaluation and dependability assessment of software important to safety is an essential and difficult aspect of digital systems safety justification
- The concern is with detecting and removing residual design errors
- These errors might be a risk of common-cause failure (CCF) that could defeat redundancy or defence-in-depth
- To provide adequate confidence, extensive work is under way at the IAEA on software verification techniques


(DRAFT V3.4)

DEPENDABILITY ASSESSMENT OF SOFTWARE FOR SAFETY INSTRUMENTATION AND CONTROL SYSTEMS AT NPPs

9 June 2015

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2014

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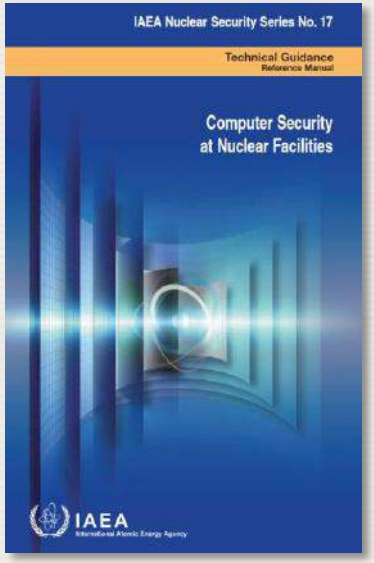
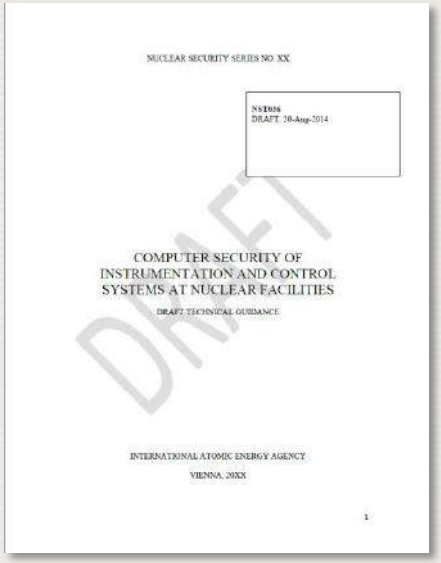
Computer security

- Nuclear I&C systems provide safety functions
- They may be targeted by adversaries for sabotage resulting in unacceptable or high radiological consequences
- A cyber-attack can cause an initiating event and/or can undermine the performance of a safety function
- IAEA guidance aims to overlay security considerations on top of the systems' safe, reliable, and deterministic behavior to meet safety and security objectives at the same time





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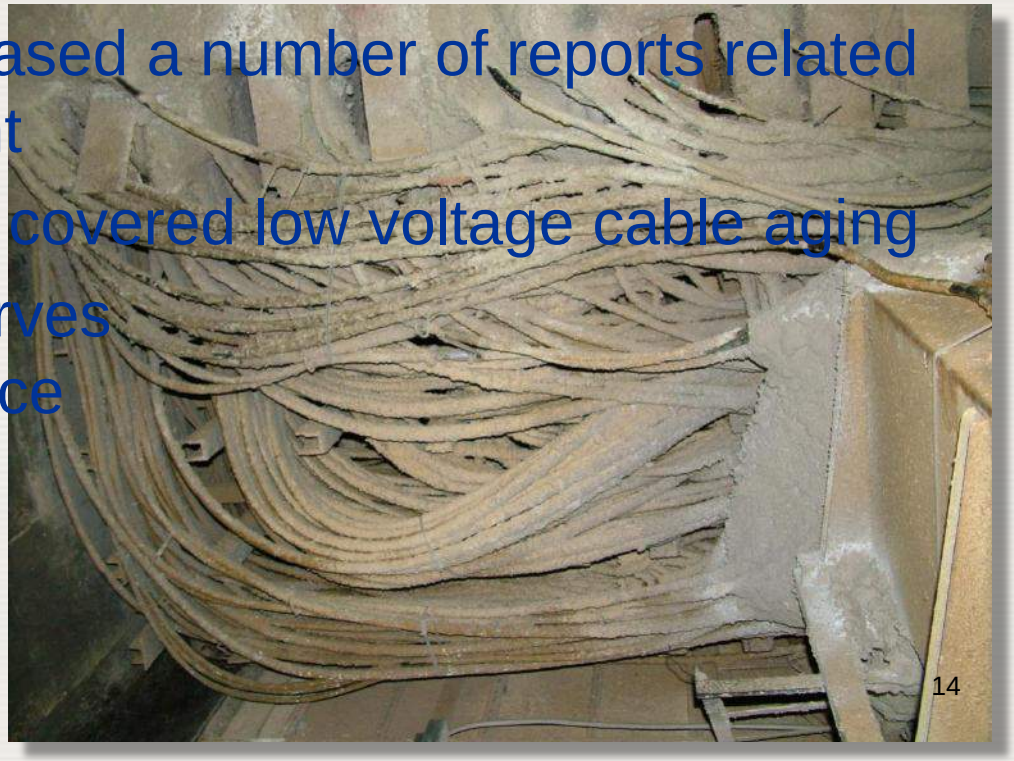
Coping with aging and obsolescence

- As most of the I&C systems are replaceable, ageing systems are not likely to create obstacles that could compromise long term operation
- However, some components, including power and signal cabling, are very difficult to replace
- The IAEA has already released a number of reports related to I&C ageing management
- A recently concluded CRP covered low voltage cable aging
- I&C modernization also serves for coping with obsolescence

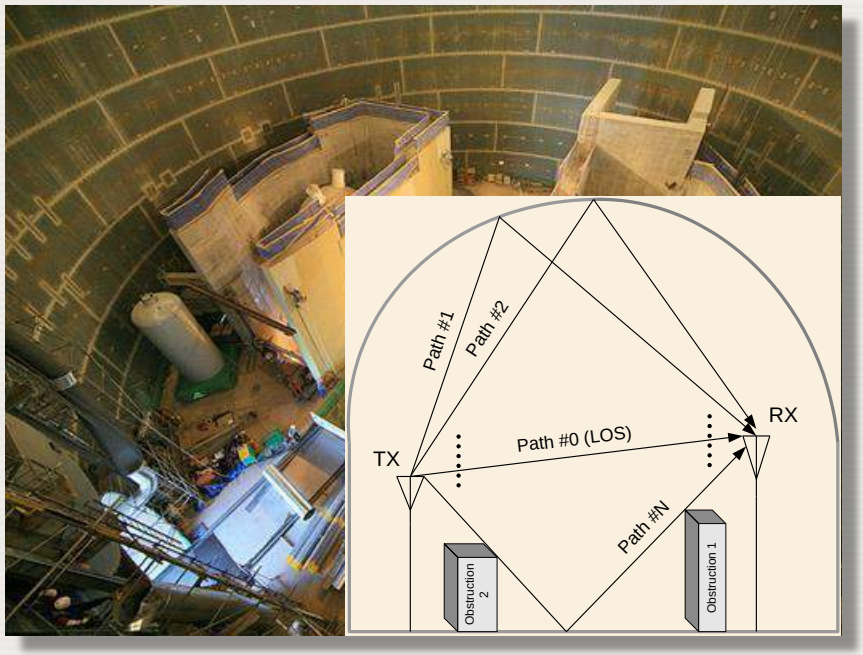


Commercial dedication

- Evaluation of COTS I&C equipment and I&C architecture
- Design considerations
- Software-based systems
- Smart devices + embedded digital devices
- Bus communications and networks
- Regulatory treatment

Use of wireless technologies in NPP I&C

- The technology is finding its way in a wider scope of applications in the nuclear power industry
  - Saving cable costs and installation time
  - Increased flexibility of information gathering through temporary sensor deployment
- IAEA coordinated research project started recently
  - The overall objective is to develop and demonstrate techniques of advanced wireless communication in I&C systems of NPPs that can be used for transferring process and diagnostic information in a nuclear specific environment



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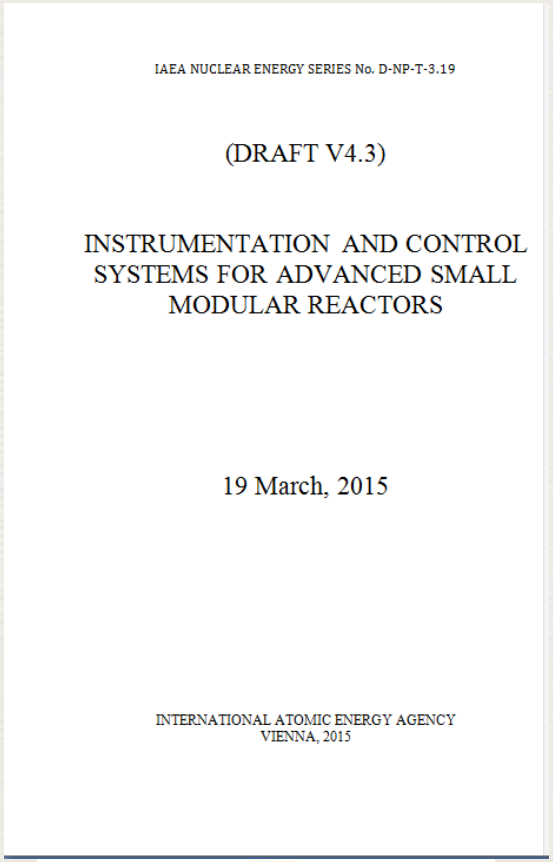
I&C systems for SMRs

- Some SMRs would operate differently from current reactors and would, therefore, need new I&C approaches
- A recently completed IAEA report evaluates the current situation and provides guidance on:
  - SMR design characteristics that impact I&C
  - SMR economic considerations
  - Regulatory considerations
  - Distinctive I&C features and issues
  - Approach to I&C design
  - I&C architecture, technologies and equipment
  - Fabrication and site integration issues
  - Concepts important for operation of SMRs
  - Maintenance


IAEA NUCLEAR ENERGY SERIES No. D-NP-T-3.19

(DRAFT V4.3)

INSTRUMENTATION AND CONTROL SYSTEMS FOR ADVANCED SMALL MODULAR REACTORS

19 March, 2015

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

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Review Missions

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IERICS missions

- IERICS: Independent Engineering Review of Instrumentation and Control Systems
  - To review the design, prototype, testing, operation, maintenance, and modernization of I&C systems
  - Conducted by a team of international experts from complementary technical areas
  - Based on appropriate IAEA documents, such as Safety Guides and Nuclear Energy Series Reports
  - Findings include a list of recommendations, suggestions and identified good practices
- IERICS mission website: http://www.iaea.org/NuclearPower/IandC/IERICS/index.html
- An upcoming mission is scheduled at the Chinese CNCS

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IERICS missions completed to date

- Doosan Heavy Industries & Construction Co., RoK, 2010
- Research and Production Corporation Radiy, Ukraine, 2010
- Joint Stock Company VNIIAES, Russia, 2012
- Joint Stock Company SRPA “Impulse”, Ukraine, 2013
- China Techenergy Co. Ltd., China, 2016

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Meetings, Workshops, Conferences

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Meetings, workshops, conferences

- 5 consultancy meetings on average in each year
- 3 technical meetings on average in each year
- 1 - 2 co-sponsorship agreements to international conferences and workshops in each year
- 2 - 4 TC training courses / workshops in each year

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Meetings planned for 2017

- Biennial meeting of the Technical Working Group on Nuclear Power Plant Instrumentation and Control, May, Vienna
- Technical meeting on Engineering and design aspects of computer security in NPP I&C systems, Q2, UK(?)
- Research Coordination Meeting on the Application of wireless technologies in NPP I&C systems Q3, Korea
- 10th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human-Machine Interface Technology (NPIC & HMIT 2017), June 11-15, 2017, San Francisco, CA, USA
- International Symposium on Future I&C for Nuclear Power Plants (ISOFIC 2017), 26-30 November 2017, Gyeongju, Republic of Korea

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Publications

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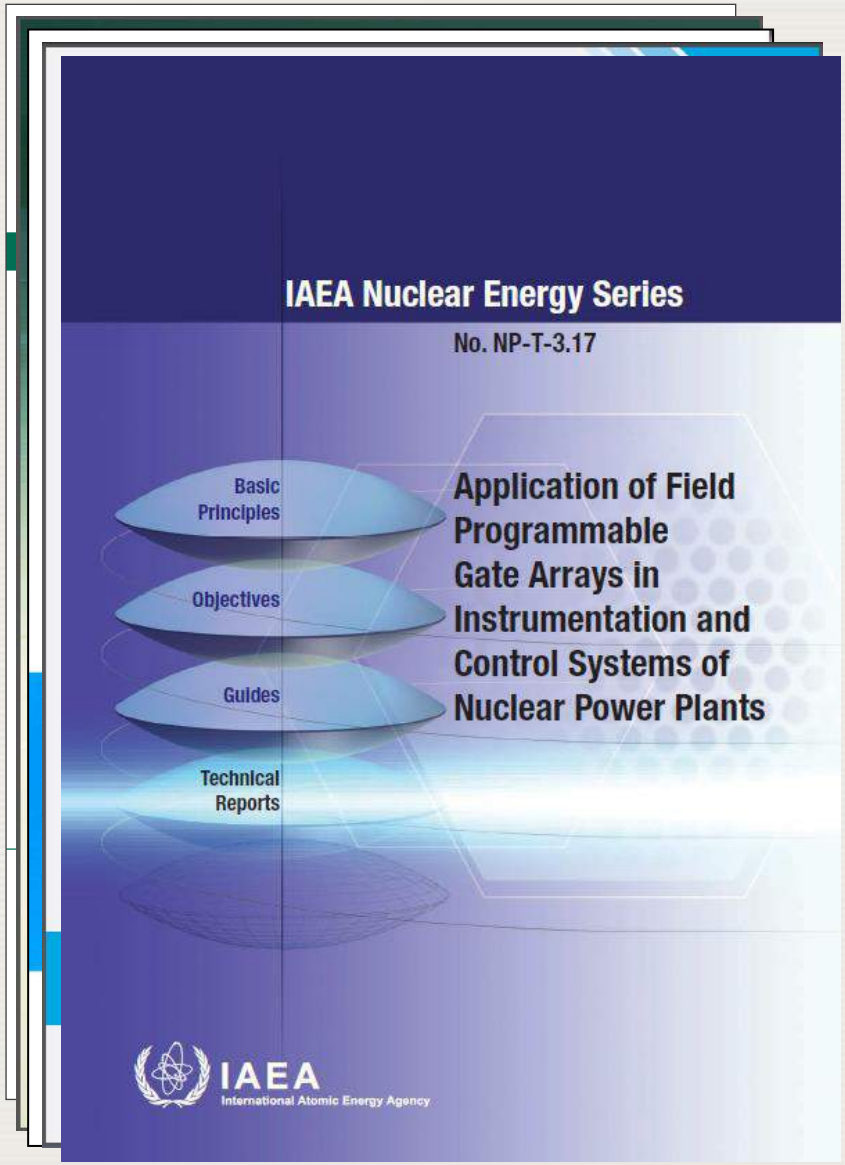
Publications

- Nuclear Safety Guides
- Safety Reports Series
- Technical Reports Series
- TECDOCs
- Nuclear Energy Series



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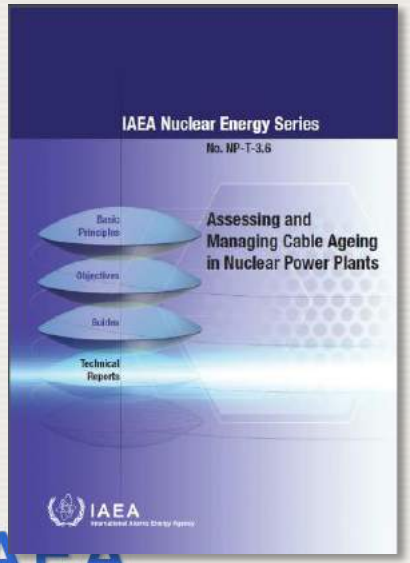
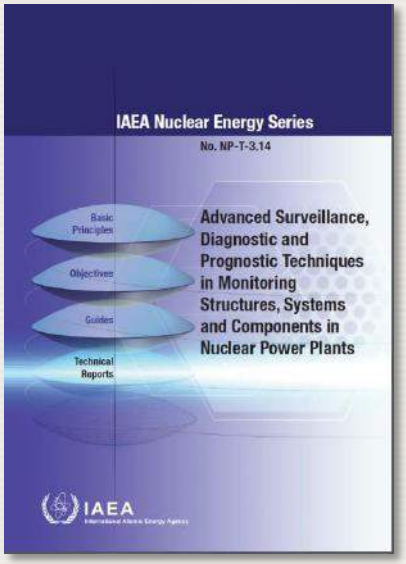
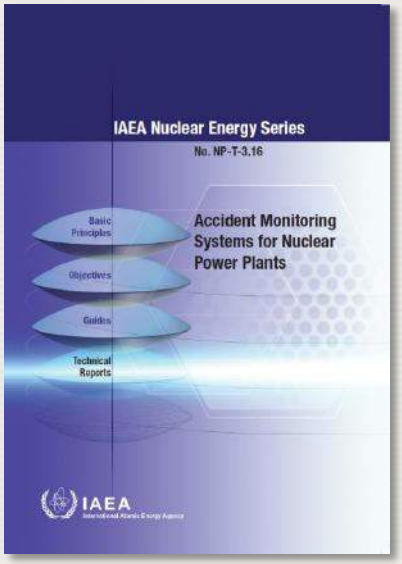
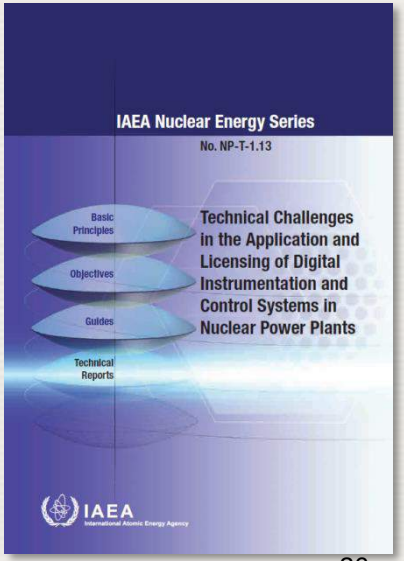
Recent NE publications

- Assessing and Managing Cable Ageing in Nuclear Power Plants
- Advanced Surveillance, Diagnostics and Prognostics Techniques in Monitoring Structures, Systems and Components in Nuclear Power Plants
- Accident Monitoring Systems for Nuclear Power Plants
- Technical Challenges in the Application and Licensing of Digital I&C Systems in NPPs
- Application of FPGAs in I&C systems of NPPs









Links to access IAEA publications

- For Nuclear Energy I&C publications
  - http://www.iaea.org/NuclearPower/IandC/
- For all Nuclear Power Engineering Publications
  - http://www.iaea.org/NuclearPower/Engineering/Publications/
- For all Nuclear Energy Series publications
  - http://www.iaea.org/OurWork/ST/NE/NESeries/ClickableMap/
- Publications in general
  - http://www.iaea.org/Publications/index.html

IAEA Nuclear Energy Series Document on the "Application of FPGAs in I&C Systems of NPPs"

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The need for an IAEA publication

- The IAEA has played a significant role and co-sponsorship in the international discussion on FPGAs
- The technology is finding its way very rapidly and the Member States needed guidance in the area
- To date, there has been no IAEA report available on the application of FPGAs

Objective

- To summarize current knowledge, best practices and issues associated with the application of FPGA based solutions in nuclear power plants
- To describe development processes and tools as well as licensing issues
- The document is intended to be used by Member States to support the design, licensing, and implementation of FPGA-based systems. Potential users are:
  - Nuclear power plant operators
  - Technical support organizations
  - Regulatory bodies
  - Research and development organizations
  - Manufacturers/ vendors

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Meetings to produce the document

- "Position paper" drafted in the 4th and 5th FPGA workshops in 2011 and 2012
- First Consultancy Meeting
  - Vienna, 11-14 February 2013
- 6th FPGA workshop
  - Kirovograd, Ukraine, 8-11 October 2013
- Last Consultancy Meeting
  - Vienna, 17 to 21 March 2014

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4th Workshop on the Application of FPGAs November 2011, Chatou, France

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5th Workshop on the Application of FPGAs October 2012, Beijing, China

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List of participants at the 1st CS meeting

- Andrashov, A. — Radiy, Ukraine
- Naser, J. — EPRI, United States of America
- Arndt, S. — US NRC, United States of America
- Seaman, S. — Westinghouse, United States of America
- Eiler, J. — International Atomic Energy Agency
- Glockler, O. — SunPort SA, Switzerland
- Thuy, N. — EdF R&D STEP, France
- Zeng, H. — SNPAS, China

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6th Workshop on the Application of FPGAs
8-11 October 2013, Kirovograd, Ukraine

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Break-out sessions to review the draft

1. Introduction to the FPGA Technology
   Sergio Russomanno
2. Methods and Tools for Development and Verification
   Nguyen Thuy
3. Qualification and Licensing, Doc. chapter: Mark Lawford
4. Applications, FPGA-based Replacement Systems and New Designs, Steve Seaman




List of participants at the last CS meeting

- Eiler, J. International Atomic Energy Agency
- Russomanno, S. Global Nuclear Solutions Inc., Canada
- Thuy, N. EdF R&D STEP, France
- Gassino, J. IRSN, France
- Arndt, S. US NRC, United States of America
- Naser, J. EPRI, United States of America
- Glockler, O. SunPort SA, Switzerland

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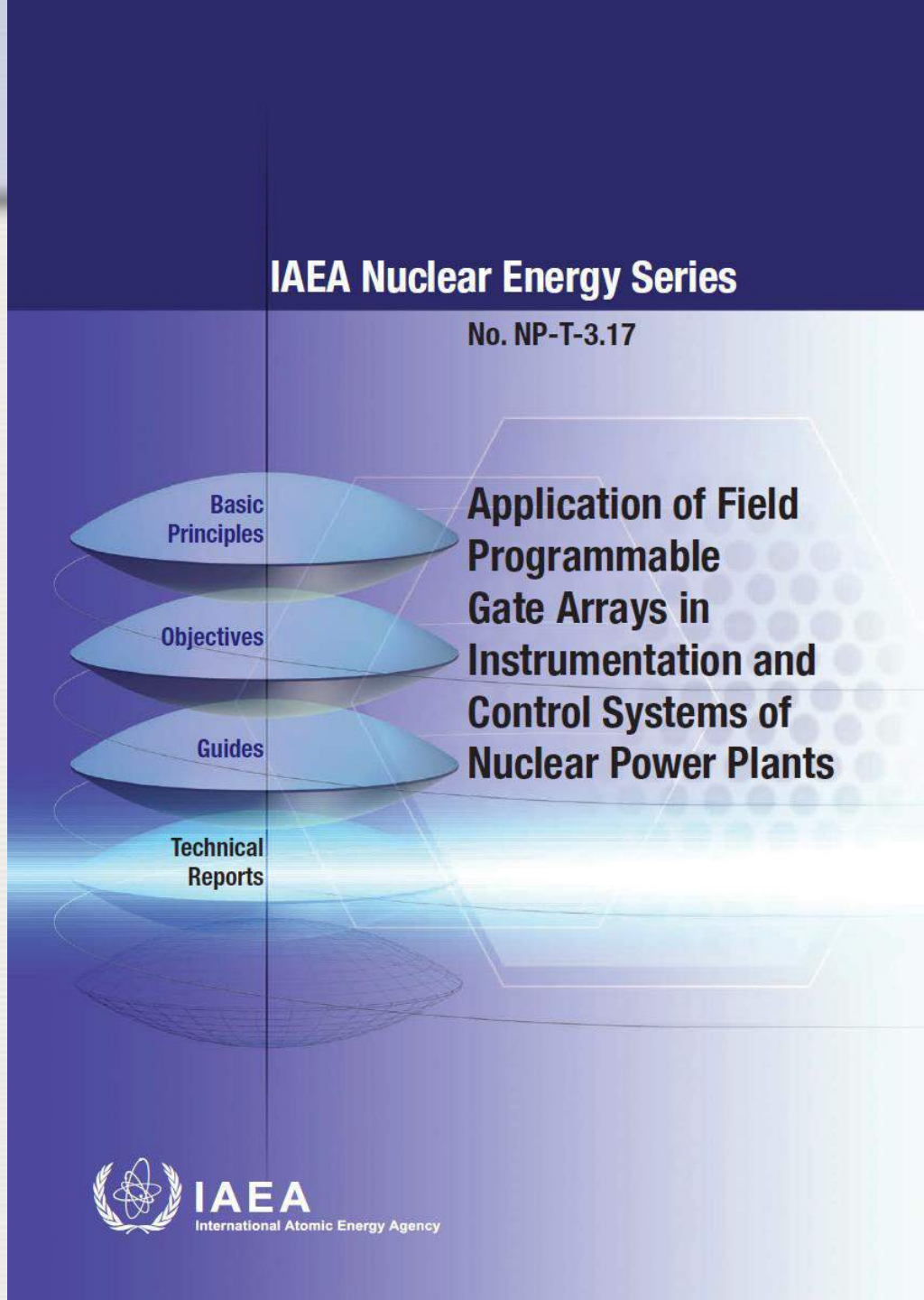
The IAEA report

- Nuclear Energy Series
  - NP-T-3.17
- Chairman: Joe Naser
- 79 pages
- 6 main chapters



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Structure

- Foreword
- 1. Introduction
- 2. Introduction to FPGA technology
- 3. Methods and tools for development and verification
- 4. Licensing
- 5. Replacement systems and new NPP designs
- 6. Summary
- References
- Annex I: Specific application examples and experience
- Annex II: Typical life cycle for an FPGA platform
- Glossary

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Introduction to FPGA technology

- FPGAs within the HDL family
- Differences between HDL and software
- What are FPGAs?
  - Comparison between FPGAs and CPLDs
  - FPGA related technologies
  - FPGA programming process
  - FPGA based systems development life cycle
- General application areas suited to FPGA based implementations
- Advantages of FPGA based I&C systems
- Challenges with FPGA based I&C systems

Methods and tools for development and verification

- Design guidelines
  - 12 subsections (e.g. pre-developed designs, coding rules, fault tolerance, diversity, testability, etc.)
- Verification and validation
  - 7 subsections (e.g. simulation, test coverage, formal verification, hardware testing, etc.)
- Tools
  - 4 subsections (quality, integration, cyber security, and life cycle)

Licensing

- Environmental qualification
- Functional demonstration
  - 7 subsections (e.g. acceptance process of the pre-developed resources, development life cycle, analysis and verification, integration and validation, etc.)
- Regulatory perspectives on FPGA technology, licensing and standards
  - 14 subsections, e.g.
    - the application of existing software based guidance for FPGA licensing
    - standards for FPGAs
    - documentation
    - reduction in variations in standards and countries' regulations
    - simplification of regulatory requirements and structure

FPGA based replacement systems and new NPP designs

- Replacements and upgrades in existing plants
  - One-for-one module replacements or upgrades
  - Multiple module replacement
  - Replacement of entire systems
- FPGA based I&C systems and devices for a new NPP design

Publication

- The report is available now on the IAEA publications website:
  - http://www.iaea.org/Publications/index.html

Thank you for your attention!