9th International Workshop on Application of FPGAs in NPPs

A case for the adoption of FPGA technology in the implementation and replacement of equipment and systems in NPPs

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Presentation Outline

- Facts to Consider
- A case for Digital
- Some questions to consider and tentative answers
- Concerns about digital technology
- Addressing the concerns
- A case for the adoption of FPGA technology in the implementation and replacement of equipment and systems in NPPs
- Summary
- Questions for consideration

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Facts to consider

- **Approx. 40% of the world's 450 nuclear reactors have some digital I&C upgrades of safety related systems.**
- **The 60 reactors currently under construction will incorporate some form of digital I&C technology.**
- **Maturity reached in the development of products design and V&V facilitates solutions to plant performance and obsolescence issues.**
- **Conventional analog instrumentation is obsolete, equipment and parts are difficult to obtain in the market, expensive and not necessarily more reliable than digital.**
- **CFSI (Counterfeit, Fraudulent, Suspect Items) threat makes reliance on SS (Second Source) suppliers risky.**

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Facts Cont…

- **Main goals of regulators and industry are to achieve safe, reliable and cost efficient operation of reactor fleets.**

- **Means to achieve the above:**
  - Improve equipment and plant reliability.
  - Minimize impact of obsolescence.
  - Reduce costs.

- **None of the above can be achieved without the adoption of digital technology.**

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A Case for Digital

- **The goal to construct and operate safe, reliable and cost efficient NPPs cannot be achieved without the adoption of digital technology.**

- **Main reasons are that:**

1. Digital technology's multiple resources and features allow designers to:

  - Create very reliable applications thus reducing initiating events.
  - Minimize spurious reactor scrams/trips at a significantly lower cost than analog based applications.

2. Conventional analog technology may not be a viable option in the foreseeable future (likely as soon as during first life extension periods).

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A Case for Digital Cont…

Improve equipment and plant reliability

- It is way simpler to implement redundancy in digital architectures than it is to do so using analog technology.
- Hardware components are reduced by approximately 80%, thereby reducing the probability of random failures.
- Maintenance activities are also significantly reduced. Therefore technicians can focus on other plant activities.
- Digital technology allows implementation of advanced control strategies that could not be achieved by hardware only. This is also a contributor to plant reliability.

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Improve equipment reliability Cont…

- Diagnostics can be greatly expanded by the use of digital technology. This contributes to plant reliability.

- Digital I&C enables better performance monitoring and easier access to plant data.

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A Case for Digital Cont…

Reduced exposure to Obsolescence

- All electronic components will eventually become obsolete. Therefore, managing obsolescence in their life cycle is critically important.

- A typical plant contains approximately 17,000 I&C components. - Up to 25% of those components can be at or near the point of obsolescence.

- The ability to use proven digital strategies would be a solution to the obsolescence of analog components.

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Reduced exposure to Obsolescence Cont…

- NPPs have a collective experience in the usage of digital technology amounting to thousands of “unit years”.
- The adoption of digital technology has resulted in reductions in initiating events.
- Candu plants have been using digital technology in safety related systems such as reactor control since the 70s and in special safety systems, such as Shutdown Systems since the 80s and have experienced no unsafe events.

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Reduced Cost

- **Simpler design:**
  - Easier to implement applications with the desired redundancies and architectures.
  - Easier to implement design changes.
  - Easier to implement advanced control strategies.

- **Lower maintenance and operating costs:**
  - More efficient performance monitoring.
  - Easier access to plant data.
  - Lower component and inventory counts (less spares as well).
  - Higher system reliability (due to less components).
  - Lower component prices.
  - Higher capacity factors.
  - Reduction of maintenance related man-hours.

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Questions to consider

- **In spite of the proven advantages of digital over analog, the inevitability of obsolescence and soon to come unavailability of analog devices, why is it that many utilities are reluctant to use digital technology in the modernization of safety and safety related systems?**

- **Since conventional analog technology is on its way out while digital is here to stay for at least the duration of life extended NPPs, why is it that reluctance to adopt digital is not considered a threat to the safe, reliable operation and financial viability of NPPs?**

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More Questions and some tentative answers

- **There is a perception in the industry that the cost and risk of licensing digital applications offsets all the benefits posed by reliability, obsolescence and otherwise lower costs resulting from the adoption of digital technology.**

- **What is it that must be done by the industry in order to take advantage of digital I&C and thus make safety and safety related systems more reliable without incurring in significant cost escalation?**

- **For the industry to benefit of the advantages of digital technology and thereby improve NPPs reliability, reduce costs and solve obsolescence problems, we must identify and address regulator's concerns.**

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Concerns about digital technology

- **Present position of most regulators is that FPGA/PLD safety and safety related applications should be treated similarly to microprocessor-based systems. That is not likely to change.**

- **Difficulties in quantifying software reliability and the lack of a universally accepted methodology.**

- **Cyber security issues. These are concerns affecting the whole software industry.**

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Concerns about digital technology Cont…

- **Digital I&C more prone to CCF requiring 100% testing and diversity:**
  - **100% software testing might be difficult to achieve except for low complexity applications.**
  - **Unless we find acceptable alternatives to 100% testing we may be limited to implementing digital solutions to low complexity applications only and in the process miss out on the advantages.**
  - **As a result, we could lose the opportunity to apply all the benefits that digital I&C brings (higher reliability, resiliency to obsolescence and lower costs) including the implementation of safer applications, e.g. self diagnostics**

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Concerns about digital technology Cont…

Regulatory Guidance:

- BTP 7-21, "Digital Computer Real-Time Performance".
- BTP 7-19, "Evaluation of Diversity and Defense-in-Depth in Digital Computer-Based I&C Systems".
- DI&C-ISG-02, "Diversity and Defense-in-Depth Issues".
- NUREG-6303, "Method for Performing Diversity and Defense-in-Depth Analyses of Reactor Protection Systems".
- NUREG/CR-7007, "Diversity Strategies for Nuclear Power Plant Instrumentation and Control Systems".

- NUREG-6303 and 7007 are not sufficiently specific on how to achieve diversity within the same technology.
- Perception in the industry that there is an unstable or insufficiently clear regulatory framework for the application of digital technology.

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Measures that are (or could be) taken to address concerns about the application of digital technology in NPPs

Common Cause Failure

- Section 1.9 of BTP 7-19 Revision 6, “Design Attributes to Eliminate Consideration of CCF” provides criteria to deal with CCF, i.e. Diversity, and Testability.

- FPGA technology provides solutions to diversity issues both as diverse to a CPU based system or as two diverse FPGA based systems.

- **And one more question:** Is the fact that FPGA technology applications can be implemented without embedded software or operating systems given enough credit when comparing it against similar CPU based applications?

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Measures that are (or could be) taken to address concerns Cont…

- **Cyber security threats**
  - Programs to counteract cyber attacks being implemented by the industry and regulators.
  - FPGAs offer the most effective solution due to their intrinsic resilience to cyber attack.

- **Unstable or insufficiently clear regulatory framework**

  The US NRC has drafted an Integrated Action Plan to Modernize Digital Instrumentation and Controls Regulatory Infrastructure in order to address the issues that are preventing wide-spread modernization (reference SRM 15-0106).

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Measures that are (or could be) taken to address concerns Cont…

Difficulties in quantifying software reliability.

- There are tools such as Bayesian Belief Networks (BBN) that allow evaluation of complexity and determination of how it affects reliability.

- **Is the industry taking adequate advantage of the Lessons Learned, OPEX and performance data accumulated through thousands of reactor-years of experience with digital I&C applied to safety and control systems?**

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Measures that are (or could be) taken to address concerns Cont…

- **Unpredictable failure modes**

  FPGA puts better control of failure modes at the designers' disposal.

- **Obsolescence**
  - Analog solutions affected the most. HDL mitigates obsolescence due to portability of HDL code between various FPGA-chips produced by different manufacturers.
  - Suitability for reverse engineering, especially (due to its flexible architecture) for Form Fit Function (FFF) replacements of equipment and systems, makes FPGA technology very attractive for refurbishment applications.
  - Therefore, FPGA technology is less affected by obsolescence and offers a better solution to present obsolescence problems affecting the industry.

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Measures that are (or could be) taken to address concerns Cont…

- **100% testing is possible and practical for simple applications.**
- **100% S/W testing might be difficult to achieve for complex applications.**
- **Some possible solutions for complex applications:**
  - To run black box validation cases on software development tools to ensure no CCF.
  - Application designers to avoid the use of commercial s/w by developing their own tools and white/black box testing it.
  - Use performance data accumulated through the use of commercial development tools.
  - Treat complex applications as composed of numerous simple applications and test each piece separately. This might be easier to accomplish using FPGA technology.

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A case for the adoption of FPGA technology in the implementation and replacement of equipment and systems in NPPs

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Improve equipment reliability	FPGA/PLD applications treated similarly to CPU-based systems.			FPGA technology applications don't include embedded S/W or OS. Is there any credit given to this fact? If not why not?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Improve equipment reliability	The lack of a universally accepted methodology for quantifying S/W reliability	Tools such as Bayesian Belief Networks (BBN) might help evaluation of S/W complexity and reliability.		FPGA technology applications don't include embedded S/W or OS. Is there any credit given to this fact? If not why not? Is the industry taking advantage of LL, OPEX and performance data accumulated through thousands of reactor years of experience with digital I&C?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Improve equipment reliability	Cyber security issues.	Programs are being implemented by the industry and regulators	FPGAs offer the most effective solution due to their intrinsic resilience to cyber attack.	

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Improve equipment reliability	100% S/W testing difficult to achieve for complex applications.	1. Run validation cases on tools 2. Designers to develop and test their own tools 3. Use commercial development tools data 4. Treat complex applications as composed of numerous simple ones and test each piece separately.	Treating complex applications as composed of numerous simple applications and testing each piece separately might be easier to accomplish using FPGA technology.	FPGA technology applications don't include embedded S/W or OS. Is there any credit given to this fact? If not why not?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Improve equipment reliability	Digital systems are considered to be more susceptible to Common Cause Failures	Section 1.9 of BTP 7-19 provides criteria to deal with CCF, i.e. **Diversity, and Testability.**	1.Treating complex applications as composed of numerous simple applications and **testing** each piece separately might be easier to accomplish using FPGA technology. 2. FPGA technology provides solutions to **diversity** issues both as diverse to a CPU based system or as two diverse FPGA based systems	Is the fact that FPGA technology applications can be implemented without embedded software or operating systems given enough credit when comparing it against similar CPU based applications?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Reduce Exposure to obsolescence	Obsolescence affects all electronic equipment.	Reliance on SS suppliers and procurement of sufficient spares. Both have financial implications. SS supply poses the additional risk associated with CFSI.	Lower impact on FPGA due to portability of HDL code. Flexible FPGA architectures make them more suitable for reverse engineering solutions to obsolescence.	Since Analog is on its way out while digital is here to stay for at least the duration of life extended NPPs, why the reluctance to adopt digital is not considered a threat to the safe, reliable operation and financial viability of NPPs?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Reduce Costs	FPGA/PLD applications treated similarly to CPU-based systems.			FPGA technology applications don't include embedded S/W or OS. Is there any credit given to this fact? If not why not?
	Perception that there is an unstable or insufficiently clear regulatory framework for the application of digital technology.	SRM 15-0106 under preparation by the US-NRC to address issues preventing wide-spread modernization		1.In spite of the proven advantages of digital over analog, the inevitability of obsolescence and soon to come unavailability of analog devices, why is it that many utilities are reluctant to use digital technology in the modernization of safety related systems?

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A case for the adoption of FPGA technology Cont…

Objective	Concerns about digital technology	Solutions to concerns as addressed by industry and regulators	How FPGA technology improves the solution.	Questions worth asking.
Reduce costs	Perception that there is an unstable or insufficiently clear regulatory framework for the application of digital technology	SRM 15-0106 under preparation by the US-NRC to address issues preventing wide-spread modernization		What is it that must be done by the industry in order to take advantage of digital I&C and thus make safety related systems more reliable without incurring in significant cost escalation?

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Summary

- Conventional analog equipment will all but disappear from the market before many reactors complete their extended life.
- Digital technology is a mature, reliable option as demonstrated by the thousands of reactor-years of operation, in safety and control applications.
- There are risks associated with postponing adoption of digital technology and clinging instead to analog products that are difficult and expensive to find in today's market and don't offer the flexibility and features that allow us to build more reliable, safer and less expensive I&C systems.
- There is a perception in the industry that there is an unstable or insufficiently clear regulatory framework for the application of digital technology.

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Summary Cont…

- For the industry to benefit of the advantages of digital technology it is imperative that we understand regulator's concerns and hold discussions to address those concerns on the basis of solid evidence provided by operating experience.

- Main goals of regulators and industry are to achieve safe, reliable and cost efficient operation of reactor fleets and none of this can be achieved without the adoption of digital technology.

- In spite of the proven advantages of digital over analog, the inevitability of obsolescence and soon to come unavailability of analog devices, many utilities, including those that have had positive experience with digital applications, are reluctant to use digital technology in the modernization of safety related systems.

- There is a perception in the industry that the cost of licensing digital applications offsets all its benefits.

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Summary Cont…

- Several of the most critical concerns about the application of digital technology discussed in this presentation can be successfully addressed by the adoption of FPGA technology, among them Common Cause Failures, Cyber threats, obsolescence and failure modes.

- For example, RPC Radiy has been involved in the design, manufacturing, applications and installation of FPGA based safety and control systems for over 20 years, in nuclear facilities in Ukraine, Bulgaria and Argentina with a high degree of success in dealing with all above issues.

- There are questions that need to be addressed in order to evaluate whether the decision to adopt technology and the methods chosen to reach those decisions are sound and evidence based. In the next slides I submit those questions to practitioners and regulators in this audience, for discussions in forums such as this workshop.

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Questions for consideration

1. In spite of the proven advantages of digital over analog, the inevitability of obsolescence and soon to come unavailability of analog devices, why is it that many utilities are reluctant to use digital technology in the modernization of safety related systems?

2. Since Analog technology is on its way out while digital is here to stay for at least the duration of life extended NPPs, why is it that reluctance to adopt digital is not considered a threat to the safe, reliable operation and financial viability of NPPs?

3. What is it that must be done by the industry in order to take advantage of digital I&C and thus make safety related systems more reliable without incurring in significant cost escalation?

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Questions for consideration Cont…

4. Is the fact that FPGA technology applications can be implemented without embedded software or operating systems given enough credit when comparing it against similar CPU based applications?

5. Is the industry taking adequate advantage of the Lessons Learned, OPEX and performance data accumulated through thousands of reactor-years of experience (hundreds of which using FPGA technology) with digital I&C applied to safety and control systems?

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Thanks for your attention.

Questions?