Use of Advanced Digital Controls in NPP Applications

A Case Study and Application to U. S. NPP Retrofits

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- Korea Hydro & Nuclear Power Co. Ltd. has been in the forefront of use of digital controls throughout its fleet since 1990
  - Yong Wang 3 & 4 (2x1000 MW) completed in 1992-'93 became "reference plants"
    - RPS ESFAS CPCS, PCS (Plant Control System)
  - All subsequent plants are derived from reference plants
    - Total installed - 17,716 MW
    - Total all-digital since 1990 – 8,000 MW (with 4000 MW ↑ by 2010)

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- Korea Power Engineering Co. Ltd. acts as owner's engineer in writing I & C specs and contract execution
  - State-of-the-art technology requirements pushed even further
    - Avoid early obsolescence (prior to contract end)
    - I & C designs require specific system performance parameters
      - System requirements are driven by design basis
    - Specification requirements drive large development effort during project
    - Safety/non-safety are isolated but data is wheeled between; speed of response is vital and mandated by I & C design basis

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- KHNP Directive – Standardization
  - **Plants are derivatives of reference in layout look, feel**
    - Op consoles must look and feel identical at all plants
    - System response, regardless of vendor, must be identical at all plants
    - 24/7 emergency engineer guides operators – plant HMI and system response must be identical
  - **Entrusts KOPEC to carry out this mandate in I & C area**
    - Write system specification in conjunction with plant design basis
    - Qualify vendors
    - Review proposals for technical compliance

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- Plant Control System (BOP) for Ulchin Units 5 & 6 (2 x 1000 MW) is basis of case study
  - System size per unit >14,000 I/O and >2,000 controllers
  - Safety and non-safety applications plus MUX I/O
  - Use of control switch modules (nearly 1,200/unit) and MA stations (over 50)
    - Next plants, Shin Kori 1 & 2 and Shin Wolsung 1 & 2 (now under construction) will have soft control in Rad Waste. Shin Kori 3 & 4 (to be built starting 2010) will have total soft control in NSSS and BOP

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- KOPEC specification focus guides selection of vendors and project execution in five key areas;
  a) High reliability; Fault tolerant system
  b) Functional segmentation to minimize propagation of failures and to match plant physical layout
  c) Validation and verification of system architecture and operation for regulatory compliance/licensing
  d) System performance criteria (intimate part of correct plant operation)
  e) Global long term support (25+ years demonstrable commitment)

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- KOPEC specification points to the commonly accepted standards in use/recommended in nuclear reviews
  - IEEE 7-4.3.3
  - IEEE 730
  - IEEE 1012
  - ASME NQA-1
- Part of license application to KINS is proof of conformance to above independently audited by KOPEC and KHNP inspectors at various project milestones

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NQA1 Procedures and Process
System/Software development life cycle model

- RFP - Customer request for proposal
- Product/Project Development Plan
- - IEEE 1058-1998, IEEE 1490-1998
- PQP - Project Quality Plan; IEEE 730-1998, IEEE 730.1-1995
- SRS - System Requirements Specification; IEEE 830-1998
- SVVP - System Verification and Validation Plan
- SDD - System Design Description;
- IEEE 1016-1998, IEEE 1074-1997
- STP - System Test Plan;
- IEEE 829-1998, IEEE 1008-1987, IEEE 1012-1998
- SIP - System Integration Plan; IEEE 1074-1997
- SCMP - System Configuration Management Plan;
- IEEE 828-1998, IEEE 1042-1987
- SAR - System Safety Analysis Report
- SVVR - System Verification and Validation Report; IEEE 1012-1998
- Project Post-Mortem Report
- - Post-project evaluation report; IEEE 1490-1998

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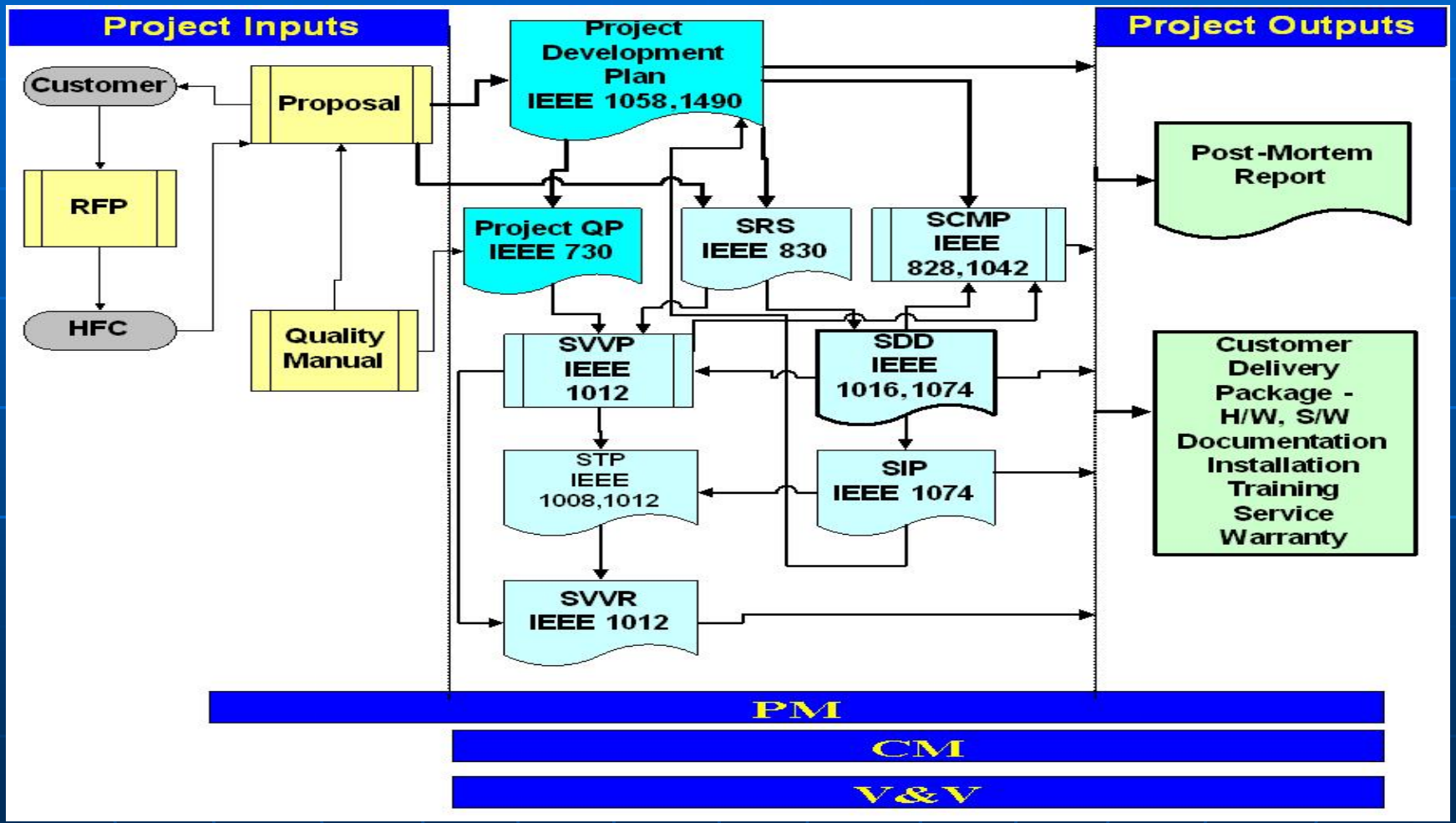

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- **Selection of Qualified PCS Vendor – KOPEC Focus**
  - **Operability and Maintainability**
    - System must be trouble-free between scheduled refueling outages
      - **Five 9's availability**
      - **Hot swappable PC boards with no system degradation**
      - **Diagnostics to minimize MTTR to minutes**
      - **Long term support/non-obsolescence policy (contract requirement for 25+ years)**
  - **Performance**
    - **Performance is intimately part of plant safety and operation designs. Systems must meet exactly; designs cannot be adapted to system deficiencies or alternative methods**
    - Reliability and Availability
      - **Redundant features fault-tolerance (and minimizing fault propagation) match exactly plant functional segmentation**
      - **Deterministic networks are mandated – guaranteed thru–put is vital**

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- Selection of Qualified PCS Vendor – KOPEC Focus (Cont.)
  - Licensability (most vital)
    - Proof of standards/spec. compliance/licensability through experience list
    - Proof that owners' engineer's designs and requirements are traceable from drawing to exact system operation and speed of performance

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- Regulatory compliance and licensability are two overriding concerns used in the final evaluation
  - Can the system provider validate and verify the application designs and implementation to the satisfaction of regulators
  - Can the system provider validate and verify the system architecture and operation meets specification and plant design basis
- Both require extensive auditing and system testing

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- Ulchin 5 & 6 PCS Experience
  - Orders placed in early 2000
  - Systems were shipped a year apart
    - Unit 5 shipped June 2003; commercial on June 2004
    - Unit 6 shipped July 2004; commercial July 2005
  - Both have proven field performance meets specifications
    - Use of MUX I/O saved millions of dollars of hardwiring
      - Bridge of non-safety to safety via fiber optics
  - High speed communications between trains, division, MUX including fiber created one giant “backplane”
      - Seamless throughput

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- Ulchin 5 & 6 PCS Experience (cont.)
  - Audits were conducted by KHNP representatives and KINS representatives
    - Prove internal processes and procedures for all phases of system H/W, S/W and application and testing comply with the specified standards
    - Testing of system to prove correct implementation to support licensing:
      - Prove faithful reproduction of owners' engineer's design in system documentation
      - Prove accurate translation of application design into logic code
      - Prove via line-by-line, point by point testing

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- Ulchin 5 & 6 PCS Experience (cont.)
  - Engineering workstation tool (OneSTEP™) provide(s)d multiple benefits:
    - Reduced engineering man hours (project and on-going maintenance) by nearly 2/3's
    - Provides system change management and documentation
    - Provided key link in V & V trail from design to end result during FAT and audits

Use of Advanced Digital Controls in NPP Applications

- Lessons for U. S. Nuclear Industry
  - Korea has routinized approval and use of digital controls for safety and non-safety (15 year history)
  - Systems match exactly the functional segmentation (one-to-one loop bases) of the I & C design and field implementation
  - System supplier must be able to adapt standard system and develop or modify to suit design (flexibility due to owning technology)
    - In turn must be able to commit (proven experience) to long term (25+ years) support

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- Lessons for U.S. Nuclear Industry (cont.)
  - Systems supplier must demonstrate licensability
    - Adherence to QA standards (NQA1, 10CFR 50 App. B, others)
    - Adherence to software/hardware development standards (IEEE 1012, others)
    - EWS tool that facilitates design – to - end-result traceability
  - Do not reduce or abandon level of rigor demanded of suppliers (even with shrinking interests by system suppliers)