Instrumentation and Controls For Future Nuclear Power Plants

The Advanced Reactors Technical Summit IV & Technology Trailblazers Showcase

February 8-9, 2017
Argonne National Laboratory

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I&C Will Continue to Enable Nuclear Power as Advanced Reactors are Deployed

New I&C is Not Necessary for Functionality

Improved I&C is Necessary for Acceptable Performance

- Enabling lower operating costs and higher plant reliability
- Advanced power reactors are not currently operating in market economies
- Advanced reactors have had substantial I&C related performance issues

Older I&C technologies remain viable

Multiple advanced reactors were built and operated decades ago
Emphasis of I&C Will Shift Towards Enabling Improved Performance In Future Nuclear Plants

More detailed condition and process knowledge
- Increasing automation – increased availability, lower staffing costs, improved grid transient response
- Maximizing component life
- Enabling improved component performance
- Support for safeguards

Increased passive safety
- Larger operating margins & slower accident progression facilitates use of complex digital logic
- Passive shutdown and passive decay heat rejection decrease safety significance of I&C (except for monitoring)
Advanced I&C Facilitates Maximizing Plant Economic Performance

- Operations & Maintenance
  - Automated/remote maintenance
  - Highly responsive load following
  - Shorter outages - diagnostics
  - Automating security functions

- Process Measurements
  - Distinctive coolants (opaque)
  - Higher temperatures (increased corrosion)
  - Integration with process heat users
  - Test facility instrumentation

- Condition Monitoring
  - Condition-based, risk-informed maintenance ⇒ avoid unplanned outages
  - Functionality of passive safety SSCs
  - Fuel performance
  - Remaining life evaluation

Lower Costs
Improved Performance
Greater Certainty
Deeply Integrated I&C Will Be a Key Difference Between Past and Future Nuclear Systems

- Sensors and controls have not typically been embedded in nuclear power reactor components
  - High speed simulation and signal processing was not available in the first nuclear era
  - Dense sensor interconnection expands the set of degradation mechanisms that can be observed
- Embedded I&C enables faster control reaction and increased stability in the event of component failures compared with traditional control
  - Traditional approach to large component design is to include mass, large margins, and tolerate inefficiency as cost of doing business
- Makes inherently unstable configurations stable → smaller, lower mass, lower cost, more reliable
  - Railroad—AC traction drive locomotives enables 50% thrust increase
  - Industrial tools—Sawstop® prevents saw blade amputations
  - Aircraft/Aerospace—stabilizing fundamentally unstable wing configuration
  - Modern jet engines have experienced a 1000X reliability improvement with embedded I&C
Evaluating Remaining Useful Life Will Be a Key Mission For Future I&C Systems

• Advanced reactor designs often rely on replacing rather than developing plant lifetime components
  – Higher temperatures challenge long component lifetimes
  – Avoids requirement for multi-decade qualification
  – Increasing replacement/maintenance automation will be key to minimizing outage durations

• Improving diagnostic and prognostic technologies
  – Physics based methods - typically insufficient experience for data driven approaches
  – Increased sensor coverage to capture additional fault signatures
  – Requires assessing material conditions e.g. fracture toughness

• Automated maintenance will be a key element of component design

MSRE coolant pump with extended bolts enabling remotely controlled replacement
Instrumentation is Central to Monitoring Fissile Material Location for Safeguards

• Nuclear material must be accounted for at each stage of operations
  – Material balance measurements and key measurement points are central to safeguards

• Some advanced reactors embed more of the fuel cycle into reactor facility
  – Integral fast reactor
  – Molten salt reactors
    • Current safeguards implementations do not address implications of fluid fuel forms

• Additional monitoring likely to be required that doesn’t exist today
  – Item counting and visual accountability of fuel may not be possible

Safeguards are the technical means for the IAEA to verify that States are meeting their legally binding undertaking not to use nuclear material or other items for illicit purposes.
Adapting and Improving Process Instrumentation for Future Reactor Environments Remains Important

• High temperature fission chamber
• Improved stability temperature measurement
  – Johnson noise or pyrometry
• Increased standoff measurements
  – Radar level gauges
  – Improved pressure impulse lines
• Ultrasonics
  – High speed signal processing was unavailable in the first nuclear era
  – Under sodium viewing
  – Guided wave temperature measurement
Instrumentation Will Continue to Form the Nervous System of Future Nuclear Power Plants

• Instrumentation remains an enabling technology
  – Traditional instrumentation technologies remain viable
  – Lowering costs and increasing reliability requires improved I&C

• Integrating I&C into the plant design is key to effective operations and safeguards

• Diagnostics & prognostics can facilitate limited lifetime components