Nuclear Power in the United States

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Operating Nuclear Power Plants in the United States

- 104 (35 BWRs, 69 PWRs) with a total net installed capacity of ~100 GW(e)
- 20.2% of electricity generation in 2009
- 62 plants have approved license extensions from 40 to 60 years
- 20 license extension applications under NRC review
- 17 license more extension applications announced so far
U.S. Operating Plants Performance


U.S. Nuclear Refueling Outage Days Average

Cumulative Capacity Additions at U.S. Nuclear Facilities 1977-2015

U.S. Electricity Production Costs 1995-2009, In 2009 cents per kilowatt-hour

Source: Energy Information Administration
Updated: 5/10

Source: 1990-98 EUCC, 1999-2009 Ventyx Velocity Suite / Nuclear Regulatory Commission
Updated: 5/10

Source: Nuclear Regulatory Commission
Updated: 6/11

Production Costs = Operations and Maintenance Costs + Fuel Costs. Production costs do not include indirect costs and are based on FERC Form 1 filings submitted by regulated utilities. Production costs are modeled for utilities that are not regulated.

Source: Ventyx Velocity Suite
Updated: 5/10
New Nuclear Power Plants in the United States

- 1 currently under construction (TVA’s Watts Bar 2)
- 4 new plant certified designs (GEH ABWR, W AP600, W AP1000, W System 80+) and 3 designs under review (Areva US EPR, GEH ESBWR, MHI US-PWR)
- 12 COL license applications under NRC active review for 20 new units (more than an additional 10 being considered)
- All based on digital I&C and HSI technology
EPRI Long-Term Operation Program

• Addresses actions needed from today until end of 80-year or longer operating life
• Additional or accelerated EPRI projects to facilitate decisions in 2015 time frame
• Projects address safety, capacity factor, reliability, and/or cost
• Project areas identified:
  – Instrumentation and control
  – Materials aging
  – Nuclear fuel
  – Safety analysis
• Coordinate with DOE LWR Sustainability Program
DOE LWR Sustainability Program

• Vision
  “Existing nuclear power plants will continue to safely provide clean and affordable electricity beyond their first license extension periods…”

• Goals
  – Develop fundamental scientific basis
  – Apply knowledge in collaborative public-private partnerships
  – Apply new technologies to address obsolescence

• Program
  – 11-year program (2009 to 2020)
  – Coordinated by Idaho National Laboratory (INL)
  – EPRI working with INL and others to define R&D Pathways
Issues to Address for Viable and Robust I&C and HSI for LTO

• Several critical issues need to be addressed to allow operating plants to have long term operation up to 80 years or even more, examples are:
  – Aging and obsolescence
  – Need for new staff and bringing up their level of expertise quickly
  – Maintain high levels of safety and meet new regulatory and environmental requirements
  – Reduce the likelihood of human error, equipment damage, forced outages, exposure to radiation and other harsh environmental conditions (e.g., heat, cold, chemical) and challenges to safety
Issues to Address for Viable and Robust I&C and HSI for LTO (continued)

- Maintain economic viability (improve efficiency and reliability and reduce time to perform jobs, time on critical path during outages, need for rework)
- Leverage scarce resources
- Supplemental workers need to be trained and brought to acceptable performance levels as quickly as possible
- Technologies expected by younger generation needed to attract them into the industry

• New tools and capabilities needed to address the issues to enable extended plant operation
Proposed New Topic Areas for IAEA and Industry

• Productivity improvement through the use of modern technologies
  – New paradigms for large improvements
  – Technology pull not technology push
• Cognitive modeling and simulation of human behavior
• Human cognitive engineering for improved decision aids
Efficient and Reliable Plants Essential for Continued Long Term Operation

• Plants are doing well now but …
  – Concerns about maintaining high levels of plant performance and reliability over extended plant lifetimes due to:
    • Aging and obsolescence
    • Knowledge drain
    • Reduced staff
    • New requirements and commitments
    • Unnecessary workloads and stress levels
    • Human errors
  – Goals to improve performance and reduce costs
• We need to take advantage of technology to help us
What About New Plants?

- New plants also need to operate efficiently, reliably and cost-effectively
- Goal is to perform better than current fleet
- Should be deciding now what is needed to support high performance and reliability during construction, operation and maintenance
Global Applicability

• Although situations in countries around the world are not identical, the need to improve productivity and support staff in their tasks is global
  – Improve productivity
  – Maintain or increase productivity as conditions change
  – Efficient new plants
Why Do We Need To Do Anything Different?

• Conditions are changing
• To paraphrase a famous quote:
  – If you keep doing what you've always done, you'll keep getting what you've always gotten
• Need to use new tools and capabilities to help people do their job more effectively
  – Reduce burdensome workload and stress levels
• Need to reduce systemic inefficiencies in day-to-day, frequent and infrequent activities
  – Estimate around 70% of plant operating cost is labor
  – Compelling ROI on activities
  – Larger potential benefits from downstream activities
• Need to provide risk mitigation including reduce likelihood of human error
What Technologies Offer Solutions to Plant Needs?

- Technologies offering beneficial solutions include:
  - Simulation
  - Visualization
  - Automation
  - Interactive human system interfaces
  - Information management
  - Communications
  - Cognitive systems engineering

- Aspects of all of these are being used in cockpits
What Types of Activities Can be Facilitated in the Nuclear Power Industry?

• Technology tools and capabilities provide support for:
  – Design
  – Work planning
  – Operations
  – Maintenance
  – Training
  – Decision-making
  – Scenario testing
  – Knowledge capture
  – Information presentation
  – Dose reduction
  – Remote collaboration and support
  – …
Why Aren’t They Already Being Used Widely?

• Why are these capabilities and tools not being used more in the nuclear industry
  – Lack of awareness of the opportunities
  – Convincing business cases
  – Changes lead to new processes, new procedures, new training etc.
  – People don’t like changes
  – Lack of standards, requirements, guidance
  – …
What Can We Do?

• Identify what is possible
  – Capabilities and tools that are available
  – Applications in other industries not just the nuclear industry
  – Problems and opportunities that can benefit from tools, capabilities and approaches made possible by the technologies

• Identify what is needed to enable plant implementations
  – Gaps and limitations that require research and development
    • Includes for tools, capabilities, requirements, design and implementation guidance …
  – Management and regulatory acceptance

• Continue exploration of tools and capabilities for continuous improvement
EPRI Productivity Improvements through Advanced Technologies Strategy Group

• Group activities will be technology pull (needs oriented) not technology push (technology driven)

• Kick-off meeting June 2010
  – Technology supported applications presented by 12 groups and demonstrations shown by 9 groups
  – Brainstorming session developed preliminary lists of:
    • Plant problems / opportunities that could benefit from advanced tools and capabilities
    • Obstacles to implementation
    • Gaps and limitations that require research and development to overcome the obstacles

• Next meeting July 2011

Different is not always better… but better is always different!
Cognitive Modeling and Simulation of Human Behavior

- Human behavior can be a significant contributor to both positive and negative activity outcomes
- Modeling and simulation (M&S) used extensively in the nuclear power industry
- Sophistication of M&S in terms of accuracy, complexity, computational speed, visualization and interactivity is very impressive
- Equivalent capability does not exist for M&S of human cognitive processes
- Human cognitive models have been created and applied on a limited basis in the military, aviation, and space industries
- Substantial improvements have been made in cognitive science
- Time to start integrating human cognitive models into nuclear power industry M&S capabilities
Human Cognitive Engineering to Improve Decision Aids

• Important to provide the right information to the right people at the right time
• Also important to provide it in the right form to support better and faster decisions

The Game of 15

Goal: 3 pieces to add to 15 (can have extras you don’t use)

Rules:
• Alternate turns – select 1 game piece from the choices below
• One selected by the other player can’t be selected again
Using Human Cognitive Decision Aid

Intuitive Representation

Offense vs. Defense – easy to become "target fixated"

Representational Design transforms a Cognitive task into a Perceptual pattern recognition task
Representation Design: Turning Technology Advances into Effective Tools

The Representation Effect

Data Availability | Decision Support
---|---
1 2 3 4 5 6 7 8 9 | 7 6 9
| 1 4 3 |
Final Thought

• The opportunities made possible by technology for making a real difference in performance exist – the challenge is to take advantage of them

“The greatest danger for most of us is not that our aim is too high and we miss it… but that it is too low…and we reach it.”

– Michelangelo
Together…Shaping the Future of Electricity