The Synergies of PLiM, PLEX, and Power Uprates: Lessons Learned From Recent BWR Experience

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The Synergies of PLiM, PLEX, and Power Uprates: Lessons Learned From Recent BWR Experience

• Business Case

• Key Lessons from Implementations
  – Vibration
  – Plant Reliability & Maintenance
  – Implementation Strategy

• Conclusions
Business Case – Synergies

Operations
  Safety, Capacity Factors, Cost Reduction

Life Extension

Power Uprates – Extended Power Uprates
U.S. Nuclear Industry Capacity Factors
1980 - 2006

Capacity Factor (%)


* Preliminary
Source: Global Energy Decisions / Energy Information Administration
Updated: 4/07

Courtesy of NEI Website
Strategic Projects

Power Uprate

> Cost effective additional generation
> Economics dictate limits to uprates
  – System and component limits can be increased
  – Analytical limits (technical/licensing approaches)

Plant Life Extension

> Regulatory process straight forward
> Requires economic planning for equipment life
> Many of the same issues as power uprate planning

“In my view, the vast majority of nuclear power plants in the US could be serious candidates for license extension for up to 80 years of operation, and I believe the NRC must prepare itself to consider that question.” – USNRC Commissioner
Why EPU?

- NRC approved 108 uprates since 1977, or
- 4,600 additional MWe, or
- Equivalent of 4 to 5 reactors

1 EPU =
1 150 MW Wind Farm, or
1 Heavy Duty Simple Cycle Gas Turbine, or
1 Small Hydro Facility, or

~3-4 Year Lead Time

Competitive Investment

- COE (cents/kWh)
- Capital
- O&M
- Fuel

Wind | IGCC | Gas | Coal | Hydro | Nuclear | EPU

U.S. Nuclear Industry Cumulative Power Uprates
1977-2007

Source: Nuclear Regulatory Commission
Updated: 4/07

 Courtesy of NEI Website
BWR / Uprate Schematic

- Increased steam flow requires upgrade of key equipment
- Balance of plant including turbine/generator modifications and increased fuel cycle costs are all incremental with power level
Key Lessons from Implementations
Lesson: Vibration

Steam dryer cracking and flow-induced vibration damage on components and supports for the Main steam and Feedwater lines.

Actuators for the Electromatic Relief Valves (ERVs) experienced significant fretting and wear.
Steam Dryer EPU Experience

Event 1 - Lower Cover Plate

Event 2 - Outer Hood
Current State of Knowledge

> Recent Experience - Curved Hood Dryers
  – Hydrodynamic loads more consequential
  – Peak stresses are in internal areas making modifications more difficult
  – Current load definition tools do not adequately address in-vessel sources
  – USNRC requiring large margin to account for load definition uncertainty

> Replacement can be cost effective option
  – Reduced outage duration and worker dose offset higher capital cost. Supports life extension
  – Improved regulatory certainty
Dryer Program (NRC RG 1.20)

- Calculation of expected excitation sources
- Comprehensive and conservative dryer analysis including uncertainty assessment with a benchmarked model
- Evaluation of dryer acoustic and hydrodynamic loads at CLTP with margin for EPU using steam line measurements
- Monitoring and evaluation of dryer loads with plant instruments during power ascension with licensed limits
- NRC review/acceptance at each stage of power ascension
- EPU License Condition for dryer and piping FIV issues
- Long term commitment to follow-on inspections
Steam Dryer Innovations

Load Definition - PBLE

- No plant-specific tuning required… eliminates constant model revisions
- Reduces singularities present in other methods
- Solves both in-vessel and MSL loads
- Benchmarking with QC2 data complete
  - LTR expected in 2007

Load Mitigation

- Addressing MSL and in-vessel sources
- Retrofit option for operating plants
- Incorporate into new plant /dryer design
- Does not impact plant operation/maintenance
- Scale model testing progressing
- Provides plants with options for EPU, LCM, and PLEX

Available 2008
P20- ERV Performance

Original actuator failed due to excessive wear

- Guide Bushings wore sufficiently to allow springs to slide thru
- Guide rods jammed in bushing due to wear
- Plunger jammed in solenoid due to loss of alignment
- Actuator life was less than 24 months

GE modified existing actuator to withstand high frequency vibration.

- Hardened guide posts and guides
- More stable guide support assembly centers motion
- Dampened input into base
- Controlled tolerances on interface parts reduces lateral movement
- Engineered springs for consistent load

Electromatic relief valves (ERV)
Plant Reliability and Maintenance

Majority of the problems attributed to EPU are in the Balance-of-Plant (BOP) area and involve pre-EPU plant component deficiencies or minimal operating margins
Failure Patterns

A. "Traditional View"
   Random Failure then a wear out zone
   2%

B. "Bathtub Curve" - High infant mortality, then a low level of random failure, then a wear out zone
   4% 11%

C. "Slow Aging" - Steady increase in the probability of failure
   5%

D. "Best New" - Sharp increase in the probability of failure then random failure
   7%

E. "Constant Random Failure"
   Random - No age related failure pattern
   14% 89%

F. "Worst New" - High infant mortality then random failure
   68%

Because 89% of failures are not age related, Condition-Based Maintenance is more effective than relying on Time-Based Maintenance for these failure modes.
Existing Reliability Considerations...

Otherwise facing:
- Premature failures
- Obsolescence
- Single Point Vulnerabilities
- Unrealized benefits of operating experience

100% Power

Failure Rate

Infant Mortality

Useful Life

Time

40 Year Life
Life Extension Reliability Impact

Equipment could fail before extended life...

License Renewal/Life Extension

100% Power

Failure Rate

Time

40 Year Life

60 Year Life

Infant Mortality

Useful Life

Failure

Power Uprate Reliability Impact

Failure could accelerate with higher powers…

120% Power

100% Power

Failure Rate

Infant Mortality

Useful Life

Failure

Extended Power Uprate (EPU)

Time

40 Year Life

Combined PLEX and PU Reliability Impact

- **100% Power**
- **120% Power**

**Failure Rate**
- **Infant Mortality**
- **Useful Life**
- **Failure**

- **40 Year Life**
- **60 Year Life**

**EPU**

**PLEX**
Asset Condition Monitoring

Online - continuous monitoring & protection

3500 & TDI

Critical assets
- Steam Turbines
- Compressors
- Main line Pumps
- Recip Compressors

Online – periodic (scanning) monitoring

3300 & TDXNet™ or TDE

Trendmaster® Pro

Essential assets
- Fans
- Pumps
- Blowers
- Etc…

BOP assets

Offline – portable
Lube oil
Thermography, etc…

GE Energy
Bently Nevada

Synergy: PLiM, PLEX, EPU Instrumentation & Control

- Power Range Neutron Monitoring (PRNM)
- Turbine Control, BOP I&C
- Steam Dryer Instrumentation
Implementation Strategy

Perform a comprehensive pre-EPU assessment of the plant – AS-IS condition with plant owner collaboration

Evaluate plant procedures for all systems and components that may be affected by EPU and revise appropriately prior to implementation of EPU

Review Main Steam and Feedwater components for potential vibration and wear related degradation

Condition Monitoring and I&C Upgrades as part of evaluation process
EPU feasibility study = decision making information

Approximate Values

- HP Mod
- LP Replacement
- Chiller Mod
- #5 FW Htr $2M
- LP Stage 8 Buckets
- Cond Demin
- LP Stage 9 Buckets

Baseline ($M):
- PUSAR
- MSR/Control Panel Mod
- MELLA
- Misc. Modifications
- Customer project administration costs

Pinch Point Map Essential for Long Term Equipment Planning
Recent Examples and Results

Recent North US BWR – 20% power uprate plus modernization and margin recapture
- Uprate capacity factor highest ever – No EPU impacts

MidWest US BWR – Integrated EPU and LCM Plan
- Effective replacements vs. marginal modifications

Steam dryer options
- Modify, replace, mitigate
- Instrumentation as needed
Performance 20\textsuperscript{SM}® Point of Arrival

Synergistic Approach

1. Evaluate
   - Plant Baseline:
     - Business Strategy
     - Nuclear Island
     - Turbine Island
     - Balance of Plant

2. Solve
   - Plant Improvements:
     - Replace
     - Repair
     - Upgrade
     - Uprate

3. Optimize
   - Plant Performance:
     - M&D Package
     - Performance Guarantees
     - Multi-Year Agreement
     - Asset Optimization

Fleet • Plant • System • Equipment • Component
Conclusions

Synergies: Power Uprates, Life Extensions, and Plant Life Maintenance are cost effective means to produce additional RELIABLE MW if planned correctly:

- Vibration: Review of Main Steam and Feedwater
- Reliability Studies with Actions
  Balance of Plant Systems Maintenance and Procedures
- Have upgrade plan for BOP and I&C systems, add Condition Monitoring
  Do as much prior/coordinated to EPU to minimize risk
Summary

Long-term view - Build in increased margins and reliability for additional operating period of 20 to 40 years during plant modernization and uprate activities.

- Develop a long term strategic plan
- Evaluate best sequence of projects
- Perform overall study (GE version is Performance 20)
- Leverage Best Practice Experience and Regulatory Guidance
- Overall Maintenance Plan and Procedures
- Condition Monitoring and Digital I&C Upgrades