Life Extension and Power Uprates

James Carneal
Program Manager - New Product Introduction
Outline

• EPU Fundamentals and Economics
  • How do you achieve EPU
  • EPU: higher steam quality, FW, Steam flows.
  • Economics

• Primary concerns with EPU
  • Impact on Reliability, Design, Materials
  • Typical EPU Mods/Pinchpoints

• Impact of EPU on Plant Life Extension
  • Current EPU Experience
  • Survey of Literature
  • What are primary concerns
EPU Fundamentals
EPU Fundamentals

How EPU is achieved:

• **EPU** **reclaims the margins** available in the original plant design configuration
  – more realistic state-of-the art analysis methodologies.

• **Higher performance equipment** is installed to maintain safe plant operation.
  – The majority are in the **Balance-of-Plant & Turbine/Generator** areas.
EPU Fundamentals

Economics:

• The utility’s decision on power uprate is based on a cost/benefit evaluation – must meet the financial metrics & long-term asset management plan.

• Regulatory approval to operate an additional 20 years – a large positive factor in the cost/benefit evaluation.
EPU: Operational Domain

- EPU will reduce both ends of the core window at rated power conditions.
  - Min core flow state point will “increase”
  - Max core flow state point will be reduced

**Legend:**
- MELLLA+ = MELLLA Plus
- EPU = Extended Power Uprate
- SPU = Stretch Power Uprate
- ICF = Increased Core Flow
- ELLLA = Extended Load Line Limit Analysis
- OLTP = Original Licensed Thermal Power
EPU: Mass Flow

• EPU results in increased Feedwater flow/Steam flow:
  • Core flow: small effect since Recirc flow.
  • EPU effect: 1-2% increase in core dP
    • <1% increase in JP SJ dP
    • Reduction in maximum core flow capability
JP/EPU: EPU without Core flow increase?
Example #’s from BWR/5-251, CLTP 105%

<table>
<thead>
<tr>
<th></th>
<th>CLTP and ICF (105% CF)</th>
<th>EPU (120% OLTP, 104% CF)</th>
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<tbody>
<tr>
<td>Steam Flow / FW Flow</td>
<td>15.1</td>
<td>17.7</td>
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<tr>
<td>(Mlb /hr)</td>
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<tr>
<td>Core Flow (Mlb /hr)</td>
<td>114 (7.5*steam)</td>
<td>112.7 (6.3*steam)</td>
</tr>
<tr>
<td>Steam Quality @ core exit</td>
<td>13.2%</td>
<td>16.2% (+3%)</td>
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</table>

• Example calculation:
  • Core flow is 6.3 times more than steam/FW flow.
  • Steam quality is +3% more than OLTP.
    • 112.7/ 17.7 * 3% = 19.0% more steam for same core flow.
  • EPU achieved by increasing quality at core exit
    • multiplied by (recirc flow/steam flow) ratio.
EPU Economics

• Typical 120% power uprate:
  – cost approximately $250MM to $500MM.

• Plant economic and plant safety:
  – better reliability/availability performance
  – more robust and advanced designs of equipment upgrades/replacements.

• 7 plants at 150MWe uprate = 1 new 1100 Mwe plant
  – Cost: $1.75B to 3.5 B versus $10+B
Primary Concerns
Impact on Reliability & Design Limits

- Margin erosion due to:
  - New Operating Conditions
  - Power Uprate
  - Aging Affects
Impact on materials

- Need to gage material life.
Summary of Typical EPU Mods

1) NSSS
- Steam dryer replacement/modifications
- Power Range Neutron Monitoring system

2) BOP upgrade/replacement
- Feedwater heaters
- Condenser tube staking
- Condensate pump and/or motor
- Condensate demin filter
- Moisture-separator reaheater
- Feedpump motor and/or blade
- Iso-phase bus duct
- Torus attached piping
- Switchgear
- Cooling tower fan

3) Turbine/Generator upgrade/replacement
- High pressure turbine replacement
- Generator rewind
- Hydrogen cooler for generator

- Most utilities will include other hardware modifications to maintain equipment reliability, availability and/or higher efficiency.
- This is important to successful long-term EPU operation.
Non Hardware-Related Pinchpoints

1) Set point changes
   – calibrate to the new 100% rated thermal power condition
2) Reactor vessel overpressure design limit
3) Core thermal-hydraulic stability
4) Containment pressure/temperature limit
5) ATWS reactor vessel overpressure and containment P/T limit
6) RPV mechanical stress limit

Notes:
A) Except for item 1, the remaining pinch points are addressed by using refined methodologies to meet the respective safety criteria.
   – For example, use TRACG (3-D) vs. ODYN (1-D method) for items 2 and 5.

• GEH has not experienced a hardware mod/replacement resulting from the pinch points.
Impact of EPU on PLEX
World Nuclear Plant Age

Due to length of LE, plants will start as early as current regulations allow.

Source: IAEA
Factors Impacting EPU Planning

**EPU Pinch Points**
- Licensing safety margins requirements
- Hardware capabilities

**Control System Capabilities**
- Data Rates / Data Quality / Data Availability
- Digital upgrades improve Safety Margin

**Design Basis Documentations**
- Completeness/Quality
- Retrievability

**Other Planned Initiatives**
- Technical rework
- Licensing constraint

**Operational Margins**
- Equipment reliability/availability
- Plant Life Extension

**Project Management**
- Utility/Vendors interface
- Resources
Extended Power Uprate Experience

Various plants

Licensed Limit
Current EPU Experience

• Several EPU projects were performed with 60-year plant life assumptions

• No resulting plant modifications linked to the 60 year assumption have been experienced

• Safety licensing criteria (such as CUF<1.0) are met with current or improved methodologies
  • Some plants are very close to operational limit, and additional actions may be necessary

• Is the trend going to be the same for +60 plant life condition?
Literature Survey - Potential EPU Impacts

- RPV and Internals embrittlement
- Increased fluence
- Potential regulatory changes
- Water availability/conservation
- Cable Aging
  - Impact varies with plant specific application
- Concrete exposed to high temperature and radiation
- Weld Techniques – Repair of irradiated materials
- Other Non-technical:
  - Lack of cohesive domestic Research Infrastructure.
  - Shortfall in trained workers at all levels.
  - Public Opinion and Policy.

and the list goes on...
GEH PLEX Effort

Strategic Position

- OEM data (Strategic analysis)
- Customer (Plant availability)
- Materials (Inspection & Remediation)
- Industry (INPO, EPRI, BWRCG)
- Regulatory (NRC, EPA)

80 Year Life

Opportunity

- Clear Utility cost-benefit... life versus NPP.
- Increased Federal regulation (NRC and EPA).
- GEH will be engaged with industry, regulatory and customers for PLEX.

Timeline

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<tr>
<th>Define ... Measure ...</th>
<th>Analyze ...</th>
<th>Design ... Verify</th>
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<tbody>
<tr>
<td>Acquire OEM/field data</td>
<td>Weibull analysis</td>
<td>Strategy &amp; White Paper</td>
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<tr>
<td>Plant failure survey</td>
<td>Economic assessment</td>
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<tr>
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<td>Materials/life cycle management</td>
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<tr>
<td>ID future MT, LT Projects</td>
<td>Strategic Plan MT, LT Projects</td>
<td>NPI High ROI ST Projects</td>
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Initial Goal: 80 Year Life Asset Management Strategy and White Paper

- Clear strategic direction based on data analysis
- Clear cost/benefit analysis of future potential markets
- Multi-Generational Product Plan from short-term to long-term
What will be Life Limiting?

• Currently no known generic issue that will limit plant life to less than 80 years
• Industry must develop technical bases for high risk life limiting issues
• Individual plants must assess their risk and
  - Maintain mitigation/contingency plans for high risk issues, and
  - Maintain life cycle and aging management to avoid obsolescence
QUESTIONS?

Thank you!