NEI 08-10 [Revision 0]

ROADMAP FOR POWER UPRATE PROGRAM DEVELOPMENT AND IMPLEMENTATION

July 2009

NEI 08-010 [Revision 0]

Nuclear Energy Institute

Roadmap for Power Uprate Program Development and Implementation

July 2009

ACKNOWLEDGEMENTS

NEI appreciates the extensive efforts of the members of the Power Uprate Task Force in developing and reviewing this document, as well as their management's support for the members' participation. In particular, we would like to recognize the following individuals:

NEI Power Uprate Task Force

Nick Camilli, EPRI
Mike Carlson, Xcel Energy
Dom Claudio, Areva
Matthew Cooper, Sargent & Lundy, LLC
John Dreyfuss, Entergy
Sharon Eldridge, Exelon
Robert Field, Sargent & Lundy, LLC
Dale Graves, Shaw Group
Carl Hinds, GE Hitachi Nuclear Energy
Charles Hogg, Bechtel
Julie Keys, NEI
Mohammad Molaei, Exelon
Brian Newell, Entergy
Greg Polowy, AmerenUE
Lee Rogers, EPRI
Ray Stewart, Areva
Ron Thomas, Dominion
Mike Weber, Westinghouse
Rich Werdann, AEP
Ken Wilson, Progress Energy

EXECUTIVE SUMMARY

NEI 08-10 was developed to provide a high level roadmap for power uprate program development and implementation. This roadmap provides Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) specific guidance for:

- The Power Uprate Decision Process
- Project Development and Management
- Analysis of Equipment and Programs
- The Regulatory and Licensing Process
- Implementation

This document represents a compilation of power uprate lessons learned and was developed to improve the overall execution of power uprates. The term power uprates as used in this report refers to Extended Power Uprate (EPU), Stretch Power Uprate (SPU), and Measurement Uncertainty Recapture (MUR) Power Uprate (PU).

TABLE OF CONTENTS

TABLES

FIGURES

GUIDANCE FOR POST-FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS

1 INTRODUCTION

This Nuclear Energy Institute (NEI) document was prepared to provide a road map for the development of Power Uprate (PU) programs, including Measurement Uncertainty Recapture (MUR) Power Uprate (PU), Stretch Power Uprate (SPU), and Extended Power Uprate (EPU), (as defined below) for light water reactor plants. All power uprates refer to increases in core thermal power (reactor power) above the original licensed thermal power (OLTP) or current licensed thermal power (CLTP) level.

NEI 08-10 was developed to provide a high level roadmap for power uprate program development and implementation. This roadmap provides Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) specific guidance for:

- The Power Uprate Decision Process
- Project Development and Management
- Analysis of Equipment and Programs
- The Regulatory and Licensing Process
- Implementation

This document represents a compilation of power uprate lessons learned and was developed to improve the overall execution of power uprates. Unless otherwise noted, the term ‘Power Uprates’ (PU) as used in this report refers to MUR PU, SPU, and EPU.

1.1 TYPES OF POWER UPRATES

MUR PU - Measurement Uncertainty Recapture Power Uprates increase licensed reactor power by less than 2 percent and are achieved by implementing enhanced techniques for calculating core thermal power. This involves the use of state-of-the-art feedwater flow measurement devices to more precisely measure feedwater flow, as used in the calculation of reactor power. More precise measurements reduce the degree of uncertainty in the power level, which is used by analysts to predict the ability of the reactor to be safely shutdown under postulated accident conditions. These small uprates are typically in the area of 1-2% and are also sometimes called 10 CFR 50 Appendix K uprates, since they are performed utilizing the overpower margin assumed by the Appendix K ECCS evaluation models.

SPU - The station OLTP was generally based on the NSSS vendor-guaranteed power level. “Stretch” power is the difference between this guaranteed power level and the design power level. For BWRs, stretch power uprate covers uprates to approximately 105% OLTP. For PWRs, stretch power uprates may increase licensed reactor power up to 107% OLTP and are usually within the original design capacity and operating margins of the NSSS and BOP systems and components. Both BWR and PWR stretch power uprates typically require either no or minimal hardware changes. The actual value for percentage increase in power a plant can achieve and stay within the stretch power uprate category is plant-specific and depends on the operating margins included in the design of a particular plant. SPU usually involves changes to instrumentation setpoints but does not involve major plant modifications. Historically, nearly all SPUs were performed within the flow passing capability of the existing high pressure turbine rotor.

EPU - Extended Power Uprates are greater than stretch power uprates and have been approved for increases in licensed reactor power to as high as 120% OLTP. These uprates require significant modifications to major balance-of-plant equipment such as the high pressure turbines, feedwater and condensate pumps and motors, main generators, and/or transformers. In particular, nearly all EPUs require a retrofit to the high pressure turbine steam flow path to increase flow passing capability. BWR extended power uprates increase the core flow along the Maximum Extended Load Line Limit Analysis (MELLLA) rod line in a range of core flow from just less than rated core flow to the maximum licensed core flow. This approach allows power increases up to 120% OLTP without major NSSS hardware modifications.

BWRs have received NRC approval of a generic approach to EPU including specific criteria, analysis codes and methods, assumptions and scope through the General Electric Extended Power Uprate Licensing Topical Reports ELTR-1, ELTR-2, and CPPU [Ref.'s 7.4b, 7.4c, 7.4d].

1.2 BACKGROUND

The ability of licensees to request and receive approval for increases in licensed core thermal power has been a part of the regulatory environment from the early days of commercial nuclear power in the U.S. A number of both BWR and PWR units (e.g., Dresden 2, 3, Quad Cities 1, 2, Crystal River 3, Calvert Cliffs 1, 2, Fort Calhoun) began operations with a licensed thermal power that was increased through the licensing process due to the lifting of a variety of constraints. These early increases in licensed core thermal power pre-date and are not listed by the NRC as 'power uprates' per se, but illustrate the flexibility built into the licensing process to adjust, or increase licensed reactor power as safety and economics dictate.

Further increases in licensed reactor power (i.e., power uprates) have become economically attractive as improvements to various technologies have become available over the past four decades. Examples are briefly discussed below.

1.2.1 NUCLEAR FUEL

Improvements to nuclear fuel design and fabrication have been of the highest importance in opening the path for power uprates. Nuclear fuel has been and will continue to be subject to ever more demanding duties related to reliability, cycle length, burnup, low leakage core design, and power density (peaking factors and power uprates). To meet these demands, fuel designs have evolved through new technology and techniques. Fuel design has seen improvements in the areas of improved accident condition analyses and use of statistical methods (i.e., in use of 'as fabricated' uncertainties). Specific design changes over the past four decades have included:

- higher enrichments,
- alloy cladding,

- lined cladding,
- low gas release designs,
- improvements to burnable poisons,
- improvements related to fuel pin dimensions, spacing, and spacer design,
- improvements related to vulnerability to vibration and fretting,
- improvements related to structural stiffness and stability,
- the introduction of intermediate flow mixers, and
- the introduction of debris filters.

In addition, fuel fabrication has become more exacting with use of better controlled manufacturing processes including extensive use of statistical process control.

Fuel and core design analysis methodologies and core monitoring have improved and can be an important source of new margins for power uprates.

With these changes in place, commercially available fuel has permitted consideration of reactor power uprate as technically feasible and (potentially) economically viable for most all operating units in the U.S.

1.2.2 NSSS Design and RCPB

Generally, Nuclear Steam Supply System (NSSS) designs have included operating and accident margins to permit consideration of an increase in licensed core thermal power. Typically, little or no increase in operating reactor pressure is required to achieve thermal power uprate.

BWR Approach - For BWR units, early stretch uprates were often performed with an increase of 2~3% in operating reactor pressure. This increase helped to retain operating throttle flow margin for the HP turbine and thereby eliminated the need for HP modification. For EPU, an HP turbine retrofit is required. Because operating throttle flow margin can be achieved through the retrofit without an attendant increase in operating reactor pressure, the uprate can be analyzed and performed at constant pressure. A consequence of the simplified Constant Pressure Power Uprate (CPPU) [Ref. 7.4d] approach (for evaluation of power uprate) is the removal of some analyses normally included in the power uprate license amendment application. Rather, these analyses are recorded in the reload analysis, as documented in the Supplemental Reload Licensing Report (SRLR). The applicable core operating limits are documented in the plant- and cycle-specific Core Operating Limits Report (COLR). Although these documents are available for staff inspection, they are not submitted with the power uprate application and are not normally submitted for NRC staff review and approval.

PWR Approach - For PWR units, no change to operating pressurizer pressure is the most common approach. Some units may propose a small increase (2~3%) to improve fuel margins.

Improvements to neutron fluence through use of low leakage cores have provided additional margin in NSSS components and help to accommodate higher power levels for the long-term under power uprate.

RCPB - The Reactor Coolant Pressure Boundary (RCPB) has significant design considerations relative to normal operating and transient design conditions. In particular, the design duty for overpressure protection and required relief capacity will typically increase with power uprate. Installed capacity may have sufficient margin, or modifications to primary and/or secondary side (PWR) safety valves (SSV) and safety relief valves (SRV) may be required. To date, design considerations for the RCPB have not been a significant impediment to EPU for the uprate percentages being targeted.

1.2.3 ACCIDENT ANALYSIS AND CONTAINMENT DESIGN

Improvements to the understanding of accident response and methodologies have permitted better modeling of thermal hydraulic and fuel response. For example, for PWRs in the late 1970's, the Loss-of-Fluid Test, or 'LOFT' facility was used to conduct the first large break LOCA, as well as a number of small break LOCAs, operational transient events, and a final severe fuel damage test. A total of thirty-six (36) experiments were conducted under the auspices of the NRC and the Organization for Economic Cooperation and Development (OECD). Some of the major conclusions of these tests included:

- core thermal response in large break LOCAs is much less severe than initially projected,
- ECCS design is effective in core protection over the range of LOCA break sizes
- both two-phase natural circulation and primary system feed-and-bleed are effective in removing core decay heat
- in anticipated-transient-without-SCRAM (ATWS) events, the core goes sub-critical and pressure-relief capacity is adequate.

In addition, the development of the Alternate Source Term (AST) has permitted better modeling of accident radionuclide release and transport. This combination has again opened the path for power uprate by permitting better quantification of accident response.

Similarly, containment response analysis has evolved and improved. The use of advanced computer codes, such as GOTHIC, permit reduced uncertainty and improved modeling of containment response.

For BWRs, in-plant testing, such as that performed at LaSalle Unit 1, has provided improved quantification of suppression pool dynamic loads.

These advances, and others, in the understanding of accident response and modeling may in many cases help demonstrate the improved margins needed to support power uprate.

1.2.4 EMERGENCY CORE COOLANT SYSTEM (ECCS) SYSTEM DESIGN

Industry experience with power uprates combined with improvements in accident analysis methodologies has shown that the installed capacity of Emergency Core Coolant System (ECCS) systems is almost always sufficient without modification to support uprate design duties.

Note that for the largest uprates, modifications to Auxiliary Feedwater Systems (PWR) and emergency service water systems (or components) may be required to maintain margins. This is determined on a station by station basis.

1.2.5 TURBINE CYCLE AND BOP SYSTEMS

For MUR PU and SPU, the turbine cycle and associated BOP systems are most often acceptable without major modification. The uprate is achieved though use of original design margins.

For EPU, however, the turbine cycle and BOP systems will most often see the greatest challenges. Major upgrades to the turbine, main generator, isolated phase bus duct, main power transformer, and power train pumps (and drivers) are often required to maintain adequate operating margins. These upgrades and others (e.g., the introduction of capacitor banks) have now been completed at many stations and have been shown to be manageable, both in terms of (a) installation scheduling and budgeting, and (b) station operations following uprate.

1.2.6 CORE CALORIMETRIC

Core thermal power is continually monitored by station operators to ensure that this parameter remains within licensed limits. Every station has a Technical Specification value for limiting core thermal power. Licensees cannot knowingly operate above this limit as measured by their core calorimetric computations. These computations have uncertainties associated with the various instruments which provide input (and in other underlying assumptions). The combined effect of these uncertainties is accounted for in plant safety analyses. In particular, the measurement of the feedwater mass flow rate contributes a significant portion of the overall uncertainty in the calorimetric.

Historically, the regulator has considered that standard industry care on minimizing uncertainty in the plant calorimetric has been adequate to establish by fiat that a 2% uncertainty value for safety analyses is acceptable. This consideration traces its roots back nearly fifty years. Recently, improvements to feedwater mass flow measurement (through use of Ultrasonic Flow Meter(ing), or UFM) have provided the means to significantly reduce the uncertainty in core calorimetric computations. The US NRC has recognized this development through revisions to regulations which now permit licensing using a reduced uncertainty in the safety analysis allowance. This change was effected by revision to requirements for Emergency Core Cooling System (ECCS) evaluation models performed in accordance with the requirements set forth in the Code of Federal Regulations (CFR) 10CFR50, Appendix K (Emergency Core Cooling System Evaluation Models, ECCS), as published in the Federal Register (FR) 65 FR 34913, June 1, 2000.

Many stations have installed such feedwater UFMs and have been licensed for MUR PU. Following this uprate, a future EPU may retain the reduced uncertainty allowance or restore the original 2% allowance. Note that some stations which have followed MUR PU with EPU have elected to restore the original 2% allowance in the safety analysis. Conversely, some units have followed EPU with MUR PU (e.g., Plant Hatch 1, 2) and several plants have experienced an interest in pursuing MUR PU after a full 120% OLTP EPU.

1.3 HISTORY

As of April 22, 2009, there have been 124 approved power uprate applications; forty (40) MURs (11 BWR, 29 PWR), sixty-four (64) SPUs (22 BWR, 42 PWR), and twenty (20) EPUs (15 BWR, 5 PWR). Based on information from the Nuclear Regulatory Commission (NRC), as of April 22, 2009, there are an additional three (3) applications pending (six units) and forty-two (42) anticipated for uprate. With the favorable economics of power uprates to date, there is potential for additional unit uprates beyond those currently identified.

As noted above, the power uprate application and review process is well established for the various power levels and reactor types. Recently the NRC has improved reporting and accountability for maintaining review schedules (SECY-08-0078) and recent licensing reviews have generally been completed per the NRC timeliness goals.

1.3.1 KEY RESOURCES AND GUIDANCE

Additional information on power uprate is available from the following sources:

- NRC Website: http://www.nrc.gov/reactors/operating/licensing/power-uprates.html
- INPO 09-005 "Power Uprate Implementation Strategies - Leadership Perspective", Rev 0, March 2009
- EPRI Lessons Learned Website http://ppudb.epri.com/Default.asp
- RS-001, "Review Standard for Extended Power Uprates". NRC website: http://www.nrc.gov/reactors/operating/licensing/power-uprates/rs-001-rev-0-dec2003.pdf
- RIS 2002-03,"Guidance on the Content of Measurement Uncertainty Recapture Power Uprate Applications." NRC website: http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2002/ri02003.html
- RIS 2007-24, "NRC Staff Position on use of the Westinghouse Crossflow Ultrasonic Flow Meter for Power Uprate or Power Recovery." NRC website: http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2007/ri200724-ML063450261.pdf
- INPO SER 05-02, "Lessons Learned from Power Uprates."

1.4 OVERVIEW

This NEI document builds on lessons learned from previous uprate efforts and provides general guidance. This includes a brief overview of power uprates, the regulatory process, guidelines on targeting uprated thermal power, best practices and operating experience from previous uprates, and keys to success for licensing, implementation and operation at power uprate conditions.

The power uprate process can be divided into five stages as shown in the following figure. The various aspects of a power uprate project are further detailed in the following sections.

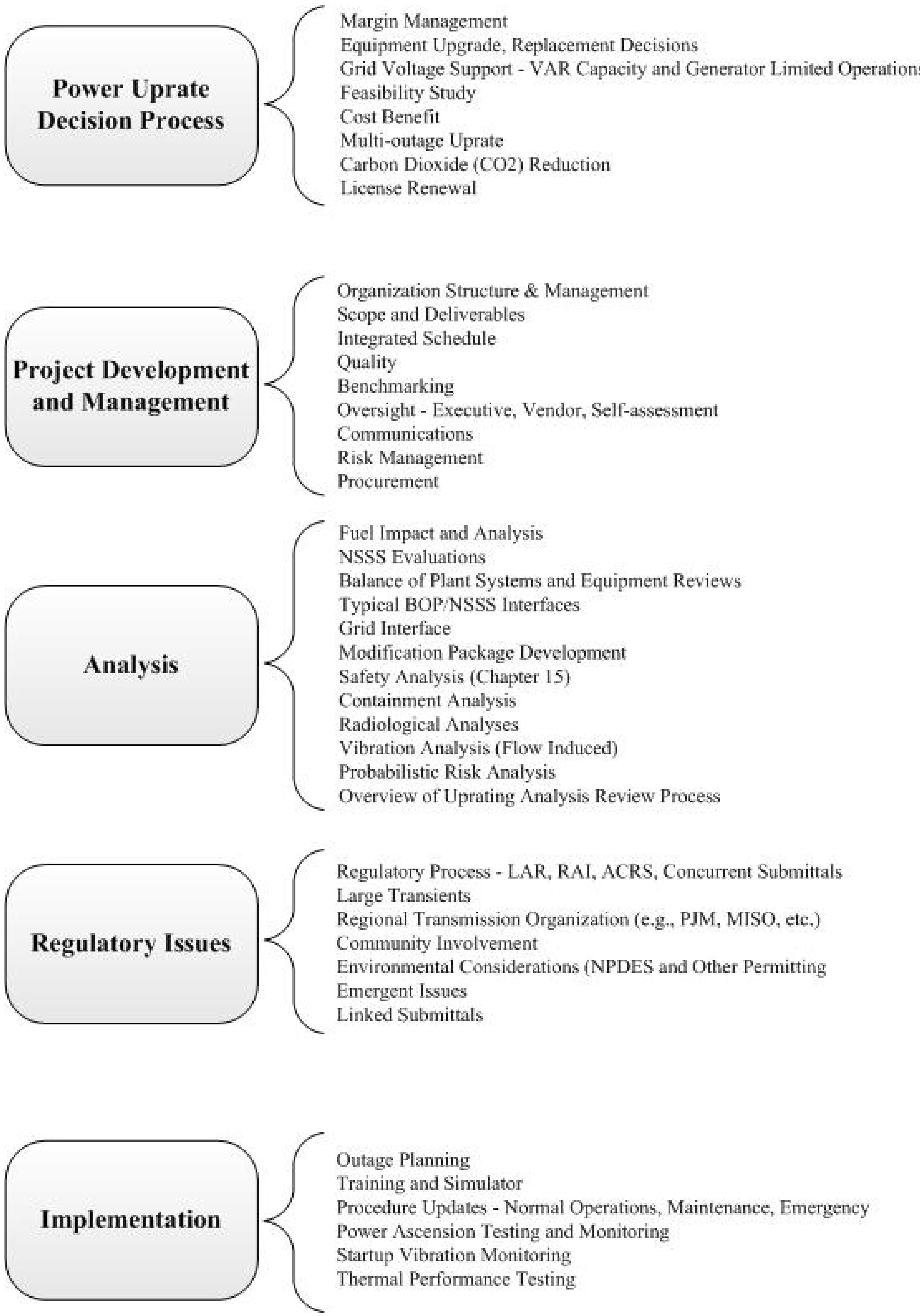


Fig. 1.1: Work Flow for Power Uprate

2 POWER UPRATE DECISION PROCESS

This section outlines the process to determine whether a PU is strategic for a utility or corporation and what major factors should be analyzed as input to this decision. Some of the variables that may factor into the uprate decision will include:

- Owner's "Green" strategy (CO2 reduction / carbon credits),
- Plant status relative to license renewal (plant life extension),
- Fuel cycle management,
- Cost Benefit, and
- Corporate cash flow.

2.1 MARGIN MANAGEMENT

Technical feasibility for power uprate and the targeted uprate power level can be distilled into the subject of margins. Power uprate is available since there are accessible margins in the design and analysis of the plant. By safely and reliably harvesting these margins, power uprate is possible. In some cases, margins must be restored or improved relative to the original design. In other cases, it is desirable to improve margins and expected reliability as a part of the power uprate program. A framework for considering margins in relation to a power uprate program is developed as described in the sections below.

2.1.1 DEFINE MARGIN

Margin is the conservatism (safety factor) included in operational limits and the design of every system, structure, and component in a nuclear plant. In quantitative terms, margin is the difference between the actual (or predicted) and required performance of a component, system, or structure. INPO has issued a good practice document in the management and design of operating margins [Ref. 7.1g]. Overall consideration of margins is outlined in the figure below. Detailed definitions are provided in the reference document.

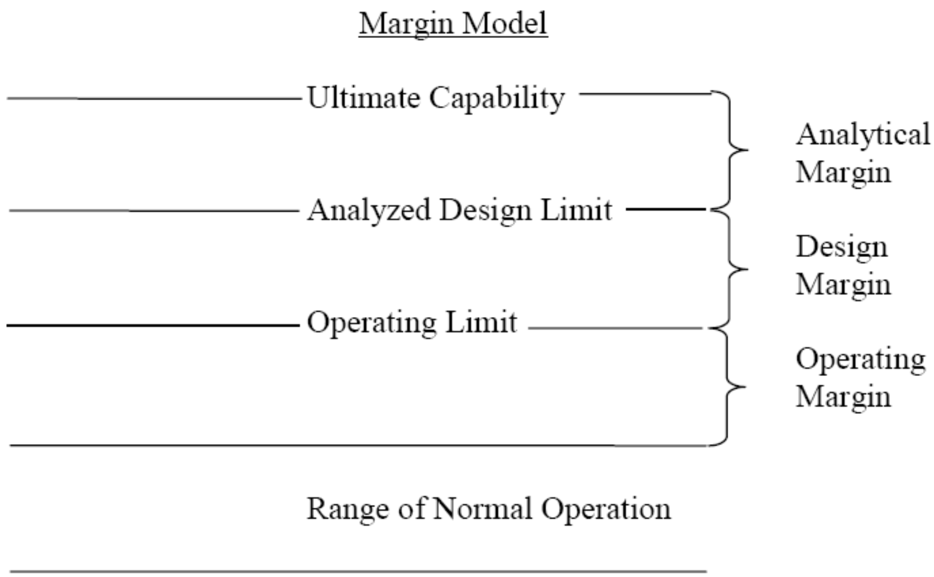


Fig. 2.1: Margin Description and Allocation

2.1.2 IDENTIFICATION

To assess the material condition of the plant and to identify and quantify margins, system design bases, plant condition reports, station interviews, and operating performance data must be generated and/or reviewed. Following are examples of operating considerations that require an evaluation of margin:

a) A structure/component's strength or ability to act as a barrier, or resist loading
b) Single parameters such as temperature, pressure, flow, electrical current, or power level
c) Safety functions such as heat removal from the reactor core
d) Time critical operator actions for events – combination of operator training, procedures, man/machine interface and human performance tools usage

2.1.3 EVALUATION

Evaluation of PU impacts on margin considers parameter dependence, cumulative effects, future demands, optimized (not maximized) design, confirmation of the plant configuration, and all modes of operation. If the original margin or design value is documented in a calculation, margin changes under PU (both decreases and increases in margin) should be documented as a revision to the calculation.

KEY POINT - In the event that design bases documents are not available or sufficient, design bases reconstitution may be required and could significantly impact project cost and schedule.

2.1.4 Recovery

There are a variety of ways that may be employed to recover margin, including: (a) corrective or preventive maintenance, (b) a change in design or in operation or testing, (c) reduced safety factor, (d) reduced calculation conservatism (possibly employing advanced analytical tools), (e) changes to design characteristics of a limiting variable, (f) a decrease in the margin of one parameter to increase the margin of another parameter, and finally (g) modification of the system or component.

2.1.5 Management

The following are best practices in effective margin management:

a) verify and resolve any differences between actual vs. originally documented margins,
b) prioritize by risk and margin,
c) identify and understand degradation of existing plant systems,
d) perform testing to verify equipment performance,
e) understand original design requirements and bases,
f) understand impacts of aggregate margin degradation, and
g) ensure that plant margins remain site-owned.

A process diagram which outlines an approach to the systematic evaluation of margins is provided per Appendix C.

2.1.6 Common Margin Management Lessons Learned

Based on previous experience, following are some specific areas for concern that have arisen during multiple power uprates (also see Section 4 and associated appendix for details on these areas):

a) Vessel internals and reactor recirculation system (BWR) – may be little margin in ability to resist increased flow effects

b) NSSS and BOP piping evaluations and available margin – minimum margin may be available to accommodate increased loadings on piping and supports.

c) Subcompartment annulus pressurization loads (BWR)

d) Condensate (CD) and feedwater (FW) train (preventive maintenance schedule for valves and pumps) – increased flow effects may accelerate degradation mechanisms such that increased maintenance frequencies are required

e) Flow Induced Vibration (FIV) (steam dryers, valve actuators, etc.)

f) Loss of redundancy (parallel pumps) in condensate and feedwater systems

g) Flow Accelerated Corrosion (FAC) (e.g., heater drain piping)

h) HP turbine throttle flow margin and main generator capability curve

2.2 EQUIPMENT UPGRADE, REPLACEMENT DECISIONS

Known system deficiencies should be addressed prior to power uprate implementation. This may result in repairs to restore original functionality and margin, analysis to establish that existing performance is acceptable, or replacement to regain margin lost through degradation. Although a system may not be adversely impacted by power uprate, an under-performing system will not operate more satisfactorily after a power uprate. A thorough evaluation of maintenance histories and component trend data must be made to identify specific areas of focus. Knowing that a power uprate will increase the demands on existing components, the cost/benefit analysis must determine whether component modernization as part of the power uprate project is appropriate.

2.3 GRID INTERFACE

The organization responsible for transmission and distribution within the station service area must be an active participant in the power uprate feasibility analysis. The power uprate has the potential to cause grid instability through increased power supply to the grid and potential loss of VAR support. The transmission and distribution entity must evaluate the impacts of the power uprate on the grid <u>as it will exist after the uprate</u>. The analytical model of the grid must include all anticipated modifications and system additions to properly characterize the condition of the distribution system when the uprate is completed (including intermediate power increases, if the uprate is to occur over more than one operating cycle). In some cases, the power uprate will require changes in breaker coordination or the addition of additional capacitance. Long lead times for these analyses should be anticipated.

See also INPO SOER 99-1, "Loss of Grid" [Ref. 7.1e]

2.4 FEASIBILITY STUDY

A detailed feasibility study is primarily technical and considered to be an essential component in the power uprate decision process. The feasibility study provides general engineering evaluations that identify the various aspects (margin issues or “pinch points”) of the station that may need significant additional analysis or modification. The station limitations at a given power level are identified as “pinch points,” the uprated power level beyond which a system, structure, component or analysis required capability will not be met without modification. A feasibility study should be thorough to ensure that potential impacts of the uprate are completely understood. Financial analysis is best completed after compiling the margin impact analysis, after all needed modifications have been identified, and after the impact on grid stability has been reasonably determined. The feasibility study must address the margin management philosophy of the utility (whether or not it is acceptable to use existing operating margins to accomplish all or part of the uprate). The more care given to performing the feasibility study, the greater the chances for a positive outcome from the power uprate. A feasibility study may or may not include cost estimates and cost/benefit analyses. As part of the study, the equipment with typically long lead times should be identified.

KEY POINT – In addition to standard front and back end fuel cost considerations for uprate, a key uprate cost in initial and on-going uprated operation is any 'special' allowance for incremental fuel costs (e.g., initial PU load, higher uranium enrichment, feeds, upgraded fuel design features, etc.). These factors need to be understood and included in projected production costs for the PU.

It is suggested that a benchmark of the goals and depth of the feasibility study against completed studies from previous projects will enhance the quality of the study and help to avoid underestimating various scope items.

2.5 COST BENEFIT

A feasibility study is typically performed to provide the Owner with the scope needed and the overall cost benefit analysis for an uprate project. The cost benefit analysis provides input to the Owner with cost and lead time information for (i) critical equipment purchases (e.g. turbine rotors, stator bars, large pumps and valves), (ii) fuel modifications, and (iii) risk (including environmental permitting risk) that may determine the true timeline for PU implementation. Utilizing the information from the feasibility study will allow the Owner to determine the benefit from the power uprate using internal (proprietary) financial assumptions and modeling.

Typically, the cost benefit study results will yield a Net Present Value or Internal Rate of Return. This result provides the basis for the business case for the power uprate project.

Limitations to full utilization of the thermal megawatts should be identified at this stage. Examples are; seasonal main generator limitations, condenser back pressure limitations, grid VAR support limitations, and secondary cooling limitations.

2.6 MULTI-OUTAGE UPRATE

To reduce the burden on plant resources and capital spending, plant modifications required for PU can be spread over multiple outages. For large EPUs requiring major modifications the recommended approach is a multi-outage implementation. The interim state of the changes may require an interim set of supporting evaluations, setpoint changes, and administrative controls. Care must be taken to understand the impact of modifications installed prior to receipt of the PU license amendment. For instance, early modification of the high-pressure turbine will result in inefficient operation prior to achieving the targeted PU power levels.

2.7 CARBON DIOXIDE (CO_2) REDUCTION

The Owner's "Green" strategy must be considered when evaluating whether new "nuclear" generation is an attractive investment compared to investing in fossil fuels or renewable energy sources for additional power. Carbon credits may be considered a factor in the cost benefit analysis.

2.8 LICENSE RENEWAL

The timing for an uprate project should consider whether the station has obtained approval for license renewal or is planning a life extension. Strategically planning for either 40 or 60+ years of plant life will have a substantial impact on the "Cost / Benefit Analysis" for the replacement of large components required for an uprate. The impact of the uprate licensing process and its integration into the station's licensing schedule, most importantly the License Renewal (LR) license schedule, is an important consideration. Additionally, site resources associated with the License Renewal project will be significant. A large portion of these site resources could be the same individuals for both the LR project and the PU project. The station resource loading should be factored into the decision as to when it would be best for the station to perform the uprate project versus the LR project. Utilities have typically made strategic decisions as to which project to work on first versus working them concurrently. A decision to work these projects sequentially has had positive results (good practice), whereas a decision to work these concurrently has had some negative results (operating experience).

See Section 5.7 relative to linked submittals to the NRC.

2.9 IDENTIFICATION AND MITIGATION OF PU VULNERABILITIES

The figure in Appendix C and descriptions in Section 4, outline the sequential steps that can be used to evaluate potential vulnerabilities of various systems and components to the new operating regime expected under PU. A formal, rigorous process such as that illustrated there will help to ensure that potential equipment and operational issues are addressed early in the PU project.

3 PROJECT DEVELOPMENT AND MANAGEMENT

3.1 ORGANIZATION STRUCTURE & MANAGEMENT

3.1.1 GENERAL

Power uprate projects require the coordinated efforts of site, corporate, and various vendor, engineering, planning, and construction organizations. To be successful, these activities must be well integrated and coordinated. Following are administrative controls and actions that can be taken by the project management team to ensure that the various organizations work together effectively:

a) Project Roster - Establish a project team with designated members representing each organization. The project manager's normal interface should be with the engineering and implementation leader for the project team.

b) Plant Representation - Establish a project team consisting of project implementation members, design team representatives, project customers and designated representatives from the plant staff for departments that are impacted or have a support function associated with the project. Consider including representatives from groups with the following functions: training, procedures group, document control group, system engineering, operations, work management, maintenance or construction departments, health physics and ALARA as applicable, chemistry, fire protection program group, security, etc.

c) Roles and Responsibilities - Clearly define roles and responsibilities, and establish a division of responsibilities table. Define the roles and responsibilities in sufficient detail to ensure that there are no gaps and the affected groups are clear as to their assigned work. Periodically update the division of responsibilities table based on newly identified interfaces, work activities, and potential changes.

d) Project Manager and Leads - Assign a project manager and project leads for engineering and the implementing organizations and establish clear roles and responsibilities early in the life of the project.

e) Project Meetings - Establish the scope, attendance, frequency and expectations for project meetings.

f) Work Scope and Boundaries - Formally define the scope and boundaries of each group's activities. This may be incorporated into the division of responsibilities table.

g) Define Interfaces - Define interface points and establish needed interface activities. This will include interface with plant departments for input, ongoing review and work activity integration, and periodic or special reviews (such as challenge boards) involving project, plant, and supplemental support groups.

h) Performance Review - For longer duration projects, establish a team member/group performance review process that includes feedback on each group's project support and on the project manager's performance with respect to achieving and advancing the project. Focus on where team members can better support each other and where team performance and interface has been effective.

i) Formal Communications - Establish channels for communication with contracted resources. For example, commercial and schedule issues should be addressed through the project manager, while technical issues should be addressed through the team lead representatives. These communications channels and activities should also address progress reporting by contracted companies supporting the project.

j) Action Item List - Establish a project-specific action item list that is reviewed at weekly progress meetings.

k) Senior Management Review – Establish routine briefs for senior management. Recommended frequency is monthly during on-going licensing evaluations and prior to PU implementation outages.

3.1.2 FLOW INDUCED VIBRATION (FIV)

It is suggested that as a special consideration, a Flow Induced Vibration Testing and Monitoring Coordinator should be appointed at the beginning of the project. FIV initiated fatigue failures or degradation have presented significant PU challenges for BWR stations when not addressed from the start of the project. The Coordinator is to be responsible to ensure that to the maximum extent practical, the station will not be subject to PU induced fatigue or degradation failures due to vibration. Responsibilities for development and control of a vibration evaluation program are described in Appendix E.

3.2 SCOPE AND DELIVERABLES

Some EPU projects have not smoothly achieved desired results because the scope and deliverables were not clearly defined as part of the project development and engineering design change process. A clear definition of the scope is even more critical when engineering activities will be performed by vendor organizations. Following are actions that should be taken to ensure the scope is adequately defined at the beginning of the project:

a) Detailed Definition – A formal detailed process should be developed to control and document scope and deliverables (including document deliverable list and scheduled issue date). Scoping meeting(s) with plant customers are needed to identify features of the modification that are desired. Factor this into the division of responsibilities matrix as the project is further developed and refined.

> KEY POINT – "Scope Creep," the addition to the project of activities not already included in the detailed, defined and agreed to scope, should be actively managed throughout the project.

b) Develop Alternatives - Develop and analyze alternative methods for accomplishing the intended project scope. Consider use of an option list to facilitate customer decision making on project options that may be desired or determined to be necessary or costly.

Alternatives analysis should consider a) equipment specific options/features, b) system integration based options/features, and c) plant integration options/features. Identification of options and features should consider operational aspects, maintenance aspects, testing aspects, procurement aspects (both initial and ongoing parts/service support), and integration with existing plant conditions (material condition, aging, obsolescence, etc.). Document and communicate the basis for the recommended/chosen solutions.

c) Engage Station Support - Identify needed support by plant groups not directly associated with the project. Examples include simulator updates and procedure and drawing update support.

> KEY POINT - An experienced Senior Reactor Operator should review any design basis changes or changes to system or equipment margins as a result of PU.

d) Pre-Operational Testing and Inspections - Identify necessary factory surveillances, testing and inspections, pre-installation testing (FAT/SAT—factory acceptance testing, site acceptance testing), installation pre-functional tests (such as continuity testing), post-modification testing, integrated plant testing, and mission time or other performance testing (MWe output tests, etc.)

e) Establish and Monitor Milestones - Establish milestones considering those internal to the project and interface milestones such as outage preparation milestones.

f) Long Lead Items - Identify long lead items and define the procurement cycle for these. This is needed at the long range planning step of the project scoping/planning process and should be refined when the project is authorized to commence.

g) Integrate Industry OE - Review and include site, fleet and industry EPU operational experience with design and installation of similar projects and equipment. Use of Institute of Nuclear Power Operations (INPO), Boiling Water Reactor Owners Group (BWROG), and vendor experience is useful to learn from previous power uprate experiences.

h) Cost Estimates - Prepare conceptual, budgetary and detailed project estimates as the planning process progresses.

i) Develop and Periodically Review Risk Factors - Develop a risk management plan addressing design, procurement, installation, and equipment/system performance risks. Identify project risks and risk management options. Determine the scope of risk management options that will be included in project scope. Periodically review and update the risk management plan through the course of the project to identify new risks and to eliminate those no longer applicable.

j) Issue Resolution Escalation Process – A clear path of escalation for project related issues should be published as part of the project work plan. This path should include a timeline for resolution at each successive level of management before escalation to the next level of management is required.

3.3 INTEGRATED SCHEDULE

To support timely implementation, engineering and construction aspects of PU projects must be completed in accordance with project integrated schedules that include allowance for unexpected delays and interfaces between vendors and other stake holders. Interim milestones should be established and monitored to verify progress toward completion of activities.

KEY POINT - For expected demands on plant resources, ensure these resources have been integrated into plant schedules or work management systems.

The estimated nominal time ranges to complete the activities required for a PU are listed in the table below. A realistic schedule for current conditions, with activities being performed in parallel when possible, shows the project inception to completion to encompass ~3 to 4 years (including allowance for Feasibility/Scoping), see below.

Table 3-1: PU Timeline

Power Uprate Decision Process	8 to 12 months
Project Development and Management	18 to 24 months
Permitting	36 to 48 months
Grid Studies	12 to 18 months
Analysis	12 to 36 months
LAR Acceptance Review	1 to 3 months
NRC Licensing Review	6 to 12 months
Implementation (Outage Strategy Dependent)	18 to 42 months

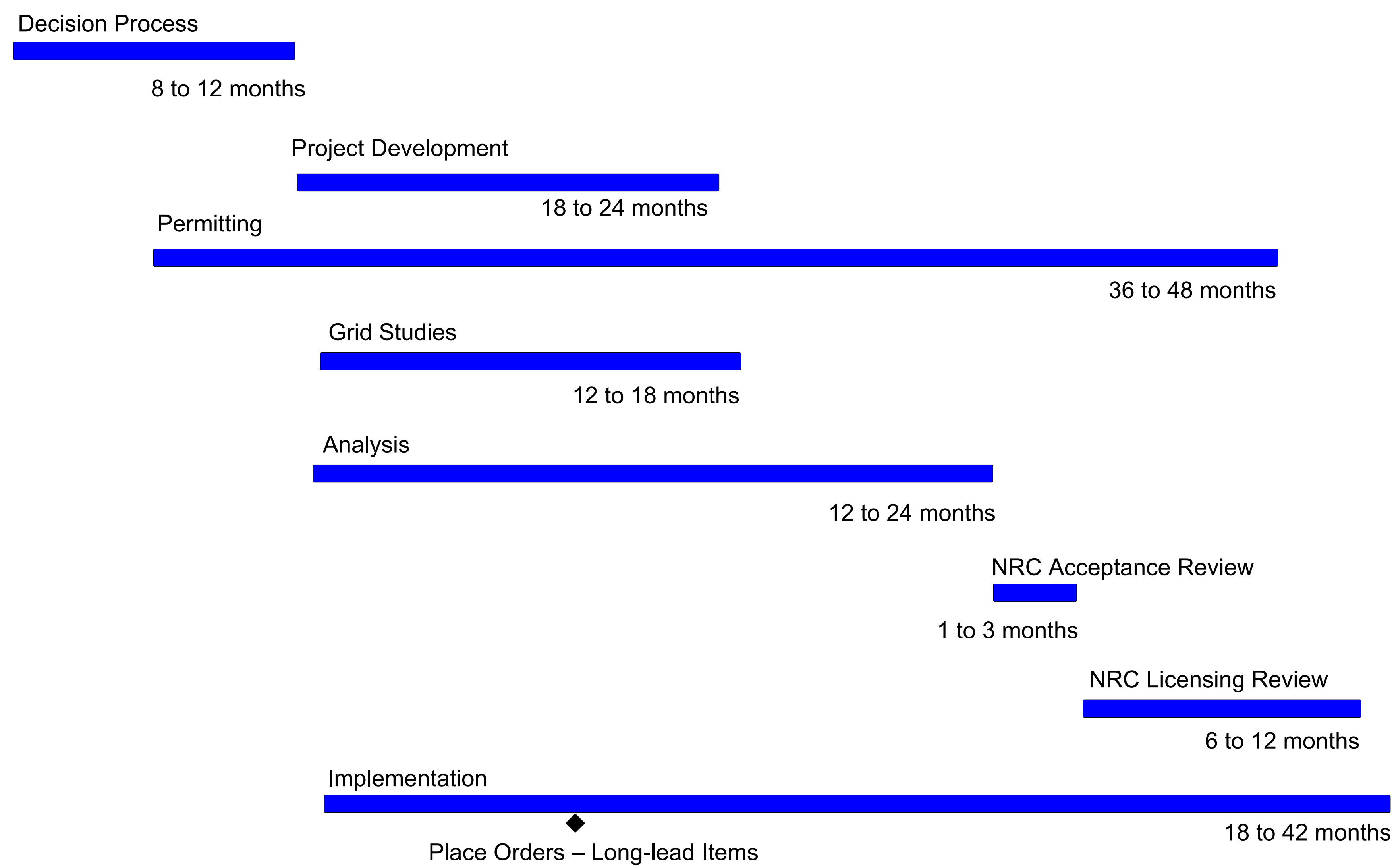


Fig. 3.1: Overall Project Schedule (Generic)

3.4 QUALITY

A variety of controls and activities must be used to ensure that PU projects are of high quality and will accomplish the intended functions without causing plant events or complicating plant operations. While many approaches can be used to verify the quality of engineering and construction work, the following are considered to be particularly effective:

a) Human Performance Tools - Require use of human performance tools including a formal review of operational experience.

b) Vendor Quality and Oversight - Validate vendor inputs, codes, and assumptions early in the design and construction process. For non-nuclear suppliers, additional quality requirements need to be included into original bid or equipment specifications and confirmed prior to contract award. In particular, non-nuclear vendors are not attuned to industry demands relative to Foreign Material Exclusion (FME) and restricted chemical cleaning agents.

   i. KEY POINT – For procurement from non-nuclear vendors, special factory oversight relative to the ex-works material condition of equipment (e.g., relative to FME and chemical cleaning agents) is warranted based on past experience (e.g., FME issues with feedwater heaters, reactor vessel chloride excursions following installation of replacement equipment).

c) Design Inputs and Criteria - Develop design requirements and input documents as one of the first deliverables so that there is agreement on the design input/requirement. Ensure affected plant departments and project implementers concur with the design requirements and inputs. This is best done prior to commencement of major design and analysis work by engineering contractors or staff to minimize engineering rework.

d) System Design Reviews - Ensure that dedicated and consistent station, project team, and affected department personnel participate in all these reviews particularly the early reviews where concerns can be adequately addressed without major rework. For plant modifications, conduct a preliminary design review, and reviews at 30%, 60% (depending on project complexity), and 90% complete or as defined by station procedures.

e) Field Work Packages - Conduct quality and readiness reviews of field work packages and ensure the work is adequately planned well in advance of commencing the work.

f) Other Reviews - Conduct source, owner, and expert third-party reviews, as applicable. Also, conduct design review board meetings, work package walkdowns, implementation review meetings, and other types of reviews in keeping with the station design review process.

g) Pre-operation and Startup Test Plan - Develop and implement a comprehensive test plan (vendor, site acceptance, other) with well defined acceptance criteria and bases. Testing must verify critical attributes of the design and demonstrate acceptable performance of component/system or plant in applicable modes of operation.

h) Risk Analysis - Detailed and thorough analyses may be performed as part of design activities. Failure Modes and Effect Analysis (FMEA) is an example of a tool that could be used to perform risk analysis.

i) Walk Downs - Conduct pre- and post-design walk downs with emphasis on ability to install the modifications, and to operate and maintain the new equipment or systems. Installation considerations should address the adequacy of installation specifications, the need for expanded tolerances, the adequacy of physical work spaces, scaffolding and special rigging requirements, ALARA considerations, review of the field change process to be used, preferred routings, etc.

j) Design Integration - Conduct design integration reviews including a review of other planned modifications.

k) Integrated Schedule - Develop and maintain an integrated schedule to establish confidence that appropriate resources are being assigned to the project. Critical milestones and decision points are established to avoid undue time pressures and to facilitate operational decision making.

l) Implementation Integration - Conduct implementation integration reviews and identify any special provisions (installing temporary jib crane, temporary shielding, temporary access provisions, confined space, etc.) that may be needed to facilitate implementation in parallel with other scheduled plant activities and will require advance engineering input.

m) Consider Challenge Boards – Use outside experts at select milestones to assess project products. This can be for discrete analyses, the LAR or other products as deemed appropriate.

3.5 BENCHMARKING

It is suggested that liberal use of benchmarking to similar projects will provide many benefits. It may be particularly helpful to work with a PU project which is tied to a nearly parallel schedule for major milestones. Benchmarking presents an efficient means of communicating best practices and lessons learned. Benchmarking and peer review in the following areas should be considered:

- Feasibility Study – scope and approach
- Project Management
- Engineering Analyses – vertical slice
- Licensing Amendment Request – comparison to similar effort elsewhere
- Startup Testing
- Procedure Updates
- Vibration Monitoring

3.6 OVERSIGHT – EXECUTIVE, VENDOR, SELF-ASSESSMENT

PU projects should consider the formal development of a self-assessment and quality plan to confirm in-process deliverable quality and schedule. Salient elements can include:

- On-site inspection of large component fabrication
- In process review of major analyses at vendor site
- Use of third party reviews of major deliverables
- Audit and inspections of external vendors
- Use of in-house quality assurance organizations
- Use of on-site cross-disciplinary review
- Use of an independent design review team for major modifications

3.7 COMMUNICATIONS

The nature of power uprate projects usually results in a separate team performing the analytical work over an extended period of time. This can result in Station Management not being kept aware of decisions being made such as modifications to restore margin or a decision to not restore margin. Communications between the project team and the plant management need to be performed often and station affected personnel need to be involved in making major decisions on scope during project duration. Any systems where margin will be reduced due to the power uprate should be specifically pointed out during these communications.

The PU project may consider establishing a formal process to consider and disposition issues related to margin. If decisions on maintaining or restoring margin appear to be arbitrary and not subject to station input, a valuable resource (i.e., station input) may be lost due to neglect. Use of a formal process on questions of margin will help to maintain station interest, ownership, and input to the project.

Effective communications between the PU project team and other station groups are important for implementation of a successful power uprate. The project manager should verify that these communications are occurring routinely and that important information is being shared among interested parties. Following are approaches that have been shown to be effective:

a) <u>Planning for Station Support</u> - Formalize activities that provide for site support and involvement in project implementation and testing activities.

b) <u>Top Management Attention</u> - Ensure periodic interactions are occurring and are of high quality.

c) <u>Upfront Communications</u> - Communicate important information prior to and during critical evolutions (e.g., during (modified) system turnover, or during power ascension testing).

d) <u>Action Item List</u> - Establish a project specific action item list that is reviewed at weekly progress meetings.

e) Communications Plan - Establish a communication plan that is reviewed and accepted by the project sponsor, project team, plant management, projects department management and corporate/fleet leadership.

f) Involvement - Establish a process for identifying and sharing decisions on PU attributes and features to ensure alignment among the design organization, project implementers, and plant customers.

3.8 RISK MANAGEMENT

Action must be taken to reduce and manage project risk and to identify potential problems that could result from implementation of PU projects that do not perform as intended. Note that the actions that must be taken to manage this risk may be different from risk management associated with cost and schedule concerns. Following are examples of activities and approaches that can be implemented as part of the project plan to identify or mitigate potential problems before they are introduced into the plant:

a) Mitigation Strategy - Identify and establish mitigation strategies for high risk design activities involving the following:

   i. Use of first-of-a-kind technology
   ii. Adaptation of non-nuclear technology to nuclear applications
   iii. Late delivery of vendor input, late start of engineering activities (time pressure)
   iv. Use of non-standard parts and equipment
   v. Subcontracted vendor support
   vi. Digital hardware/software changes
   vii. Lack of utility expertise associated with the technology
   viii. Application of implemented design on a second unit that has a different design bases and specifications

b) FMEA - Perform failure modes and effects analyses as part of design

c) Adequate Test Planning - Ensure test plans address potential failure modes and recovery / restore of system function / configuration

d) Industry OE - Conduct operating experience review early and often in the design process, and benchmark to utilities who have implemented similar PU projects.

e) Recovery Plan - Plan for recovery measures for incomplete or late vendor design outputs based on vendor performance experience.

f) Contingent Manpower - Consider impacts of plant operational events and new regulatory demands on resource availability.

3.9 PROCUREMENT

Power uprates impose increased demands on the supply chain. Some of the equipment and services required to implement a power uprate have not been procured for many years, and suppliers may be no longer available or willing to meet nuclear standards. Therefore the procurement process has large impact on power uprate schedule and success.

Procurement documents for engineering services should specifically address the scope of work to be performed, deliverables, and the approaches to be used to ensure product quality. Based on industry experience, the procurement process should address the following items that are specific to engineering for large projects:

a) Identify Key Activities - Include key activities and controls described elsewhere in this document, as they pertain to vendor-provided support including startup testing. It may be necessary to develop specific Quality Plans.

b) Quality Checks - Include requirements for internal, owner, and/or independent quality checks. Factory acceptance tests can be used to determine overall equipment acceptability.

c) Proprietary Issues - Require delivery or at a minimum, access to calculations/analyses. This may involve addressing proprietary aspects of vendor information.

d) Downstream Vendor Support - Include vendor support for testing and training content development, if applicable.

e) Qualification - Verify that the vendor meets the requirements for quality supplier, and establish the QA plan for the project, vendor or owner. Additional vendor QA audits may be needed.

KEY POINT - Some non-safety components and equipment vendors may not be able to support expected documentation requirements typical of nuclear safety programs. Additional education and clarification or use of an intermediary may be required as part of the proposal and selection process.

f) Use of Sub-suppliers - Ensure processes are in place to control/obtain input from sub-vendors.

g) Training - Specify training requirements for supplemental personnel. Training should include both specialty skills such as welding and electrical environmental qualification cable splicing as well as softer skills such as those associated with industrial safety and the use of human performance error reduction tools.

4 ANALYSIS

During the initial development and construction of nuclear facilities in the 1960's and 1970's a number of utilities recognized the potential for uprating the thermal output of the nuclear unit to increase electrical generation. Conservatism was included in the original plant system and equipment design and specification with the understanding that increased thermal power ratings would be requested at a later date based on the levels of safety and operability demonstrated by the plant at the originally licensed power. Today there is a broad base of experience to support the operation of plant components at uprated levels. In an effort to streamline and standardize the licensing review process, nuclear suppliers have standardized plant, component, and system designs to envelope a spectrum of operating conditions over a broad range of thermal power ratings.

The purpose of this section and the associated Appendix D is to provide a high level discussion of the evaluations, analyses and component design reviews that need to be performed to demonstrate that a plant can continue to be operated without undue risk to the health and safety of the public assuming the licensed power level is increased as requested. Details for the reviews are contained in Appendix D with the sections below providing an overview of the areas to be evaluated.

4.1 FUEL IMPACT AND ANALYSIS

The station "Fuel Cycle Management Strategy" has significant impact on when and if an uprate project should (or shouldn't) be considered. The development and licensing of fuel capable of supporting higher power outputs needs to be taken into consideration. (For example: Does the fuel design exist? Has it been tested? Has it been licensed? When will it be available? How to design fuel with zero leakers while uprating? What are the criteria to choose between use of a transition core or performing a full core change-out?) Spent fuel storage should also be considered. These key fuel considerations must be factored into the NSSS feasibility study due to the close interrelationship of fuel assumptions with the plant UFSAR Chapter 15 safety analysis.

The expiration date of the current fuel contract will have an impact on when an upgrade or new fuel design should be considered. The station fuel or outage strategy could include transitioning to a 24-month cycle from an 18-month cycle which could logically be the proper time for an uprate. Finally, the core redesign is fundamental in SPU or EPU analysis and licensing activities. The fuel fabrication schedule will play an important role in the decision of when an uprate is possible. An increase in core energy is typically required for EPU implementation. This needs to be addressed in the N-1 outage reload cycle to minimize the reload batch fraction for EPU implementation.

KEY POINT - Close communication early in the decision process by the PU Project Management team to both Owner and vendor fuel personnel is key to successful PU implementation.

4.2 NUCLEAR STEAM SUPPLY SYSTEM (NSSS) EVALUATIONS

The detailed evaluation of NSSS structures, systems, and components (SSCs) focuses on those specific areas in which the need for further evaluation and possible plant changes has been previously identified in the Feasibility Study. The designer will receive revisions to the design bases and/or functional requirements for the specific system/component and will determine if the installed system/component remains in compliance with the plant specific standards, design criteria, and regulatory requirements for the uprated conditions.

PU will change Reactor Coolant System (RCS) operating parameters. This necessitates the verification that each installed SSC and the associated analyses are in compliance with the design codes, standards and criteria for the revised operating conditions. In some instances it will be necessary to revise the documented analyses to account for the increased power level. Three levels of effort may be necessary to accomplish this review. Each of the three levels, a) no change to design duty, b) new duty bounded by existing design, or c) new supporting analysis is required as discussed in detail in Appendix D.

4.3 BALANCE OF PLANT SYSTEMS AND EQUIPMENT REVIEWS

Prior to performing the detailed analysis for the Balance of Plant (BOP), a detailed Feasibility Study must be completed with the key deliverable being a list of required large equipment modifications (e.g. high pressure turbine, etc) and a corresponding implementation plan including target outage(s) for implementation.

During the detailed analysis phase, the design engineer verifies the adequacy of the BOP structures, systems, components, and Instrumentation & Controls for PU conditions. This will require the upfront development of operating and design conditions for all systems based on heat balances performed for the BOP.

Based on these conditions, BOP structures, systems and components calculations are verified to ensure that the operating and design conditions are either adequately addressed by the existing designs or that further equipment modifications (in addition to the large equipment modifications identified in the Feasibility Study) are required to provide for adequate operating margin.

Appendix D provides overviews and highlights of analyses performed in the BOP area to support and justify the implementation of the power uprate.

4.4 TYPICAL BOP/NSSS INTERFACES

Uprating of the unit will also have an impact on the BOP systems and equipment. As part of the evaluation of the NSSS, the NSSS/BOP interfaces will be reviewed and changes to the interface information will be developed. The areas of the BOP/NSSS interfaces that may be impacted by PU are detailed in Appendix D.

4.5 GRID INTERFACE

Power uprate will increase power flow from the station to the grid. There are four basic issues associated with interface to the grid; (a) local grid voltage regulation, (b) avoidance of transmission system overloads, (c) grid stability as related to both large and small disturbances (e.g., oscillatory behavior), and (d) protection of switchyard and local transmission equipment (e.g., from fault currents).

Key activities related to grid interface include:

- System Studies – The PU milestone schedule must be coordinated with system studies of the grid to; (i) identify whether capital improvements (or changes to relay settings) are required in the switchyard, (ii) ensure that grid stability results are current and included in the licensing submittal, and (iii) ensure that installed hardware and protective relays will support grid reliability.

- Station Limitations – Understand historical and projected grid demands to determine if regular (e.g., seasonal) down power may be required to maintain system voltage support and plant margins. Determine whether grid devices (e.g., capacitor banks) are warranted, when and where they will be installed, and how they will be funded.
- Protective Relays - Coordinate power uprate review of main generator and station auxiliary power protective relay logic and settings with ongoing or anticipated reviews related to FERC concerns (i.e., relative to large system disturbances) [Ref. 7.5].

4.6 SAFETY ANALYSIS

A reference analysis is normally established as part of the initial licensing effort as documented in the Updated Final Safety Analysis Report (UFSAR). This is supplemented by re-analyses required for reload fuel or plant equipment or system changes. For PU, a safety evaluation is performed to confirm the validity of applicable reference analyses. If the reference analyses do not bound the uprated conditions, re-analysis using currently approved methods and appropriate input parameters must be performed.

4.6.1 DESIGN INITIALIZATION

The initial step in performing the uprate safety analysis is the design initialization. This involves the collection and review of design basis information to ensure that the uprating safety evaluation will be properly based on the actual fuel in the plant, the actual plant operating history, and any plant system changes prior to or associated with the uprating. The initialization review identifies the analysis objectives, requirements and constraints for the overall uprating.

The objective of performing the uprating safety evaluation is to verify compliance with the currently established safety limits for the specific unit with the uprated core and plant system design. This is accomplished by examining each accident presented in the UFSAR or subsequent submittals to the NRC to determine if the reference analysis remains valid for the uprating. The specific licensing design basis transients for each plant can be found in the

UFSAR. For those accidents which are affected by the uprating, an evaluation is performed to verify compliance with the applicable safety limits.

4.6.2 EVALUATION

In the performance of an uprating safety evaluation, each accident is examined and the bounding values of the key safety parameters which could be affected by the uprating are determined based on the reference analysis. These parameters form the basis for determining whether the reference safety analysis remains valid. Each of these parameters is compared with the reference analysis value to determine if any parameter is not bounded. If all of the parameters are bounded, the reference analysis remains valid and no new analysis is needed to verify that the safety limits are not exceeded. Should one or more of the safety parameters not be bounded, a re-evaluation of the accident is performed. The majority of the transient safety analysis parameters (e.g., Chapter 15 for SRP plants) are highly dependent on the design of the nuclear fuel. Therefore close coordination with fuel personnel is key to proper decision making during these evaluations.

The re-evaluation may be of two types. If the parameter is only slightly out of bounds, or if the transient is relatively insensitive to that parameter, a simple quantitative evaluation may be made. Alternatively, should the deviation be large or be expected to have a more significant or not easily quantifiable effect on the accident, a re-analysis of the accident is performed. If the accident is re-analyzed, the analysis methods follow standard procedures and will typically employ analytical methods which have been used in previous submittals to the NRC. These methods are those which have been presented in the UFSAR or subsequent submittals to the NRC for that plant, reference SARs (e.g., for Westinghouse, RESAR), or reports submitted for NRC approval. The re-analyzed accident must continue to meet the appropriate safety limit for that event in order to be considered to have acceptable results.

Typically, MUR PU will require mostly quantifiable types of evaluations with minimal or no reanalysis; while SPU and EPU will require more extensive or complete reanalysis of the Chapter 15 type events.

Accident re-analysis may also be necessary if there are any changes made to the reactor plant systems, either in configuration, performance or setpoints as determined during the design initialization phase. Should any plant or system changes affecting safety be incorporated, their impact will be determined during the evaluation.

4.6.3 BWR EVALUATIONS

For BWRs, GE has received NRC approval for a safety analysis approach to license EPU. The pre-approved licensing approach is outlined in GE's Extended Power Uprate Licensing Topical Reports (ELTRs) [Ref.'s 7.3b, 7.3c, 7.3d]. All GEHNE EPU projects to-date in the US have been uprated using the GE approach. The required safety analyses are described in the Extended Power Uprate Licensing Topical Reports as well as the CPPU LTR (CLTR) [Ref.'s 7.4b, 7.4c, 7.4d].

4.7 CONTAINMENT ANALYSIS

Containment analysis must confirm that the pressure and temperature under PU conditions would remain below design limits. For those BWR plants with containment overpressure credit currently in their licensing basis or contemplating a request for containment overpressure credit as part of the power uprate license submittal, additional analysis may be required in the special events areas.

4.8 RADIOLOGICAL ANALYSES

4.8.1 OFFSITE RELEASE AND ACCIDENT ANALYSES

Radiological offsite release and accident evaluations for power uprates are performed to ensure that the site dose limit, the site boundary dose limits, and dose limits for accident conditions do not exceed NRC limits. A number of accidents are analyzed to evaluate the impact of PU which may have an impact on the resulting doses. This typically includes LOCA, steam line break, feedwater line break, steam generator tube rupture (PWR), control rod ejection (PWR) and locked rotor (PWR). Alternate Source Term (AST) methodology may be implemented as a potential means to provide design margin in the analysis.

4.8.2 NORMAL OPERATIONS

Anticipated changes to the normal operating dose are also considered. In particular, percentage changes to N16 occupational dose in BWRs may significantly exceed the percentage increase in power level. This is due to an increase in the generation rate of N16, a decrease in the transit time, and an increase in the inventory in cross around and other pressurized components and piping. Also note that increases in moisture carryover can be expected to increase radionuclide release via condenser offgas systems for both BWR and PWR units.

4.9 FLOW INDUCED VIBRATION ANALYSIS

Regulatory Guide 1.20 [Ref. 7.2c] provides specific examples of areas to address and provides guidance in using either historical operating experience, comparison evaluations to other structures, or specific modal analysis methods as means to document adequate vibration margin in the areas of reactor vessel internals. An example of a specific NSSS component where vibration related analyses are performed for BWR stations is the steam dryer component. Flow induced vibration is also examined in the Reactor Vessel internals area as per the guidance of the Mechanical and Civil Engineering section of RS-001 [Ref. 7.2a].

There are also a number of areas in the Balance of Plant side where evaluation or analysis are performed on the impact of vibration changes due to the PU including the Main Steam Supply System, the Moisture Separator Reheaters tubes, the Feedwater Piping Systems, the Feedwater Heater tubes, and the Turbine Generator Building structural analysis.

KEY POINT – Piping systems and inline components (e.g. sample probes, thermowells) that are subject to increased flows should be evaluated relative to flow induced vibration.

Operating experience for the areas to be reviewed can be found in Appendix E.

4.10 PROBABILISTIC RISK ANALYSIS

4.10.1 ANALYSIS

Although specific NRC staff expectations for Probabilistic Risk Analysis (PRA) assessments for PU applications are contained in RS-001 [Ref. 7.2a] (MUR PU is covered under RIS-2002-003 [Ref. 7.2e]), there are no established acceptance criteria for the Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) increase directly related to PU.

Regulatory Guide 1.174 [Ref. 7.2d] contains PRA criteria which may be used to determine the suitability of PU. RG 1.174 permits CDF changes of less than 1.0E-6 per plant-year and LERF change of 1.0E-7 per plant-year, regardless of pre- power uprate PRA results. RG 1.174 also permits CDF changes in the range of 1.0E-6 to 1.0E-5 per plant-year and LERF changes in the range of 1.0E-7 to 1.0E-6 per plant-year provided the pre- power uprate CDF and LERF values are less than 1.0E-4 and 1.0E-5 per plant year, respectively.

The power uprate PRAs are normally performed by the licensee using the plant-specific PRA model. The primary impact of the power uprate on PRAs is attributable to the reduced operator action times resulting from the increased decay heat levels. The reduced time increases the operator error probability.

Previous power uprates have shown the impact of the power uprate on initiating event frequency, success criteria and other parameters to be insignificant. The increase in CDF and LERF values due to the power uprate generally meet the RG 1.174 criteria.

4.10.2 PROACTIVE DESIGN CHANGES

The station considering PU may also consider improvements to plant systems and components to reduce CDF and compensate for increases in CDF associated with the PU. This requires an upfront capability to actively perform PRA modeling for ‘what if’ scenarios. This approach will serve to minimize licensing risk and may introduce some significant improvements to plant safety with relatively small incremental cost. PWR examples include the addition or re-sizing of atmospheric dump valves, or an increase to auxiliary feedwater system flow delivery or diversity for the PU project.

> KEY POINT – Required changes to plant safety systems or components should be closely coordinated with PRA analyses to get the best ‘bang for the buck’ when modifying systems for PU.

4.11 MODIFICATION PACKAGE DEVELOPMENT

A strong well-managed configuration change process is key to successful power uprate implementation. There are usually numerous modifications performed, especially on BOP systems to support an uprate.

While quality is of the highest importance to all station modifications, the distinguishing attribute of power uprate is the number of simultaneous modifications and the potential for unforeseen or unintended interactions or consequences. While strict adherence to the station modification process is a given, for power uprate, the project management guidelines provided in Section 3 outline a solid foundation for execution of PU projects, including implementation of identified station modifications.

5 REGULATORY ISSUES

5.1 REGULATORY PROCESS – LAR, RAI, ACRS, ASLB

5.1.1 LICENSE AMENDMENT REQUEST

The License Amendment Request (LAR) for an EPU must be understood from the outset as much more extensive than that for virtually any subject. Only License Renewal and a Conversion to Improved Technical Specifications rivals such a change. It involves (re)consideration of virtually every aspect of a plant's operating license. It is NOT necessary to re-license the plant in the sense that the current licensing basis cannot or should not be maintained but it does expose the licensee to questions about the current licensing basis and whether it is more appropriate to maintain or change the licensing basis.

KEY POINT - The NRC staff could re-open licensing questions the utility may consider as resolved many years before.

Review Standard RS-001 - The applicable review standard for EPU is RS-001 [Ref. 7.2a]. This document also currently serves as the de facto review standard for SPU. This is guidance most applicable to the NRC Staff in the review of PU applications but is a document of significant relevance to the licensee as well. Additional Guidance is provided in LIC-109 for this (and all other) License Amendment Requests [Ref. 7.2b]. RS-001 includes a series of tables and explanatory comments that need to be modified to reflect the licensing basis of the plant in question. It was developed for standard plant requirements and will need to be modified to reflect non-standard aspects of a plant's licensing basis. This is especially true for a pre-Standard Review Plan (SRP) [Ref. 7.2f] or pre-General Design Criteria (GDC) [Ref. 7.2g] plant but is a necessary activity for all licensees.

The RS format affords the licensee the opportunity to articulate its understanding of its current license basis. The risks include bringing attention to unique features that may or may not appear reasonable to a current reviewer. In those cases the licensee would be well served to make sure they can adequately explain and if necessary defend that characteristic. It is incumbent upon the licensee to prepare this mark-up accurately. Further, the review necessary to prepare this portion of the LAR provides a unique opportunity to decide if it is more appropriate to change or maintain unique characteristics. The various stakeholders have a right to expect that the licensee will properly balance maintaining the status quo and making reasonable and cost-effective improvements. Finally, this is another aspect of a PU where the effort to manage margin appropriately will require a balance between extracting excessive margins while maintaining adequate safety and operational margins.

For MUR PU the NRC guidance document is RIS-2002-03 [Ref. 7.2e].

Acceptance Review - LIC-109 [Ref. 7.2b] is particularly important for PU applications. The acceptance review is a major milestone both in terms of demonstrating a complete understanding of the licensing issues to be resolved and also in terms of establishing the schedule for final implementation. NRC acceptance review takes approximately 30 – 45 days. The NRC is committed to a twelve month review from acceptance for EPU, nine months for SPU and six months for MUR PU. However, due to the complexity of PU applications, recently NRC review times have been longer.

LAR Submittal - All PU applications will require the approval of a new value for RATED THERMAL POWER in the Operating License and elsewhere. There may also be changes to TS content or UFSAR changes that would not be supportable under 10 CFR 50.59 because of the related margin changes, methods improvements, etc. A typical submittal includes TS and TS bases changes, UFSAR changes, RS-001, Safety Evaluation and an Environmental Impact Statement.

5.1.2. COMMUNICATIONS WITH THE REGULATOR

Most successful licensees have found the following to be very helpful:

a) Pre-application Meeting - Conduct a pre-application meeting as early as possible. It allows for resource planning and other feedback from the NRC. One of the key aspects of such meetings is to identify and schedule related amendment requests as discussed elsewhere.

b) Unique Issues - If there are schedule-related or unique technical questions that could be better dealt with prior to the submittal of any amendment requests, it is beneficial to do so. Consulting and participating with the industry NEI PU Task Force can be beneficial in resolving these issues.

c) Linked Submittals – See Section 5.7.

d) Regular Communication - Conduct regular meetings and/or teleconferences with the NRC. While meetings can be viewed as a resource distraction they may well advance the overall schedule.

e) RAI Responses - It is critically important that RAI's be understood before responses are prepared. Best practices include providing a draft RAI response to the NRC with subsequent discussion via conference call. This process provides both the utility and the NRC an opportunity to evaluate the RAI and proposed response to ensure the utility's response addresses the true NRC concern. Further, it is important that RAI responses be provided in a timely fashion. Some licensee processes may not be conducive to rapid-turn-around of RAI responses. That issue needs to be addressed up front by the licensee to assure that timeliness meets reasonable expectations.

5.1.3 ACRS AND ALSB PREPARATION AND EXECUTION

Most licensees do not routinely find their applications before the Advisory Committee on Reactor Safeguards (ACRS) or Atomic Safety and Licensing Board (ASLB). All EPU must be reviewed by the ACRS. All contested license applications are adjudicated before the ASLB. Any licensee contemplating an EPU needs to become familiar with and to be as comfortable as possible with these processes.

The official ACRS role is oversight of the NRC's review of the application. It is incumbent upon the licensee to support the NRC Staff with the ACRS review. Some licensees have had literally dozens of staff at the ACRS Subcommittee meeting that precedes the full committee. While this may seem extreme it should serve to alert others that this is not an activity limited to the licensing staff. It involves the entire project.

In the event the utility is required to appear at the ASLB hearing, involvement by outside counsel is likely to be needed to support contested hearings. Few, if any licensees handle such formal hearings with in-house staff. Outside counsel and in-house staff not routinely involved in such matters need to be involved in advance not after intervention occurs. The project team needs to provide adequate background information to counsel to be helpful. Further, well-qualified outside counsel can offer strategies that are intended to preclude or at least reduce the chance of intervention.

The actual process of being before the ACRS or involved in a contested hearing is time-consuming. All key PU management will need to block out time to prepare for and attend these hearings. If these managers are not familiar with such processes they must be prepared ahead of time and should consider attendance at peer meetings to get a feel for the process. Further, knowing how the participants are challenged will improve key decision making.

5.2 LARGE TRANSIENTS

The BWR Licensing Topical Reports [Ref. 7.4b] document recommendations for performing large transient testing as a part of EPU startup. Most plants can successfully justify why such testing is not desirable or required. Project specific strategy can be based in part on recent Safety Evaluation Reports (SERs) which detail how this need has been addressed. The decision to perform (or not perform) large transient testing must be made early and communicated to the NRC prior to submittal of the LAR. Since this is typically an open area of discussion, attention should be paid to other plant submittals and newer SERs.

5.3 REGIONAL TRANSMISSION ORGANIZATION (E.G., PJM, MISO, ETC.)

Regulatory interface with regional transmission organizations is highly dependent on the specific area of the country and organization transmission services for the station service territory. See Section 2.3 for additional details.

5.4 COMMUNITY INVOLVEMENT

The benefits to the community from the investment in uprating an existing unit can be significant. The positive impacts include: short and long-term employment, increased local business opportunities, increased tax revenues, and a demonstration of commitment to continued operation of the existing asset. Other impacts such as increased traffic, local municipal (i.e. police) support for large component deliveries and politics could add additional costs to the project.

Obtaining local community involvement from the beginning can help identify and resolve potential conflicts during the early phases of the project. Establishing this dialogue will help the project understand the concerns, gain local support and resolve the issues in a timely and cost effective manner.

5.5 ENVIRONMENTAL CONSIDERATIONS (NPDES AND OTHER PERMITTING)

There are at least two major environmental aspects of PU projects.

State, Local and Federal (non-radiological) requirements are unique for each licensee. Addressing these requirements can be very resource intensive and should be factored into the "Work Breakdown Structure/Schedule" from the outset. Depending on jurisdictional agreements unique to each state and region, these requirements may be enforced by a large number of agencies. Interactions could involve the Army Corps of Engineers, the (State) Environmental Protection Agency, and a myriad of state and local agencies. It will be necessary for staff responsible for environmental permitting and compliance to be more integrally involved in nuclear licensing and vice versa. Efforts to strengthen clarity in responsibilities and associated protocols are strongly encouraged.

The NRC will also require an environmental impact study sufficient to meet National Environmental Protection Agency (NEPA) requirements. If a plant has completed License Renewal, significant sections of the report may already exist.

It is likely that these efforts will produce at least some exposure to public involvement and opportunities for various communication and other outreach efforts. These may involve portions of the Owner's organization that are not regularly involved in nuclear projects. Appropriate interfaces and protocols should be established as part of any complete Project Management Plan.

There are a number of environmental issues that all licensees should consider for further discussion:

<u>A) Water Use Permitting</u> – Essentially all PU projects will impact water flows to and from 'the environment." These changes are regulated by the Environmental Protection Agency (EPA) either directly or are (primarily) delegated to the respective state. The permit is referred to as the National Pollutant Discharge Elimination System (NPDES) Permit. Other aspects of water use may also be regulated by local water commissions. As a minimum, the following issues must be coordinated with the PU project.

- i) Aquatic biota impacts, thermal discharge (seagrass, etc) – EPA 316A
- ii) Aquatic organism impingement mortality/entrainment – EPA 316B
- iii) Consumptive and non-consumptive water use

B) Other - Other environmental issues may include air quality permitting, changes in chemical treatment, and recreational use. In addition, socio-economic factors should also be included. Potential areas to be addressed include:

i) Traffic Patterns
ii) Wetlands
iii) Storm water
iv) Land Use
v) Archeological/Historical Sites
vi) Transmission Impacts
vii) Dredging operations
viii) Air quality permitting (cooling towers)

5.6 EMERGENT ISSUES

The Issue Response Guideline (see Appendix F) describes an option on how to handle future emergent issues with the potential of generic impact. The process is developed for the industry to utilize the NEI PU Task Force in developing responses to generic issues during performance of Power Uprate activities. The process is described in Appendix F.

5.7 LINKED SUBMITTALS

One key aspect of acceptance review is management of linked applications. The guidance in LIC-109 [Ref. 7.2b] discourages linked submittals. Linked submittals have been permitted by the NRC in the past. Linked submittals require early communications with the NRC.

The following potential LARs may involve linkage between the licensed core thermal power and the issue at hand (i.e., PU):

- Alternate Source Term (AST)
- Analysis Methodology (e.g., conversion to GOTHIC, best estimate LOCA, LBB)
- Improved Standard Technical Specification (ISTS)
- License Renewal
- Increase to maximum licensed core flow
- New fuel product line introduction
- Fuel cycle length

6 IMPLEMENTATION

Implementation issues run the gamut from modification problems through ramp-up testing issues. Most PU implementation plans include hardware modifications as well as set point changes and other procedural changes. These discrete items are subject to the controlling process for each station. However, the nature of a power uprate project may present unique challenges due to the aggregate effect of these plant changes and the overall power ascension testing required.

Success for the modifications should be assured through the rigorous application of the station configuration change and control processes. The major area of concern from a power uprate perspective is that there are often multiple modifications performed on the same system at one time. These types of changes require that an aggregate look be performed so that system challenges are minimized. Independent reviews by outside experts can facilitate ensuring that the big picture is evaluated as well as each individual change.

Also of concern is the time frame for implementation of modifications. Some utilities have installed modifications in the cycle preceding the uprate (i.e., N-1), which requires that they be assessed for the current licensed thermal power impacts as well as the projected uprated power level. Some modifications, such as HP turbine replacements, will result in lower MWe until the uprate is implemented due to inefficient operation at lower thermal power levels. This condition needs to be assessed and well communicated.

Note that based on past surveys, forty-six percent of power uprate implementation weaknesses fall into the following three systems:

a) Feedwater
b) Main Steam
c) Main Turbine

The main program reasons for implementation weaknesses are:

1. Poor Communication
2. Inadequately evaluated multiple changes
3. Deficient power ascension plan, testing and acceptance criteria
4. Inadequately evaluated plant changes

6.1 OUTAGE PLANNING

The outage just preceding the power uprate outage (i.e., N-1) is the opportunity for the utility to set the stage for a successful power uprate. By that time, all modifications should have been identified and a preliminary design for each should have been completed.

KEY POINT - During the N-1 outage, the design team must conduct rigorous field walkdowns and inspections for those modifications in areas normally inaccessible during plant operations to identify any necessary design changes or implementation challenges.

KEY POINT - The N-1 outage is also an appropriate time to install the vibration (and potentially other) monitoring instrumentation that will be used for any power ascension testing planned following the uprate. In this manner, the utility will collect baseline operating data for the plant and will be in a better position to evaluate the results of the power uprate testing. That instrumentation will need to be sufficiently robust to function reliably for more than one operating cycle.

An increase in core energy is required for PU implementation. For EPU, fuel economy may dictate that this issue be addressed in the N-1 or N-2 outage reload cycle to cost effectively manage the reload batch fraction for final implementation.

Forced or unscheduled outage lists should include identified contingent power uprate activities (i.e. walkdowns, testing, modifications).

6.2 TRAINING AND SIMULATOR

Each modification typically requires an evaluation to determine whether training is required for operators and/or others such as maintenance personnel and whether the modification should be implemented in the simulator.

Training is recommended to cover the power ascension test plan. This training should consider running some of the testing on the simulator as just-in-time training prior to initiating the power ascension phase. Training should include all personnel directly involved in the test, not just the control room operators. This would include engineers and others that will be collecting the primary data required for the test. Include review of (a) all acceptance criteria and (b) contingencies for failure to meet these criteria in the training.

KEY POINT – For multi-unit sites, a plan must be developed to address differences between the uprated and non-uprated units during the implementation period.

6.3 PROCEDURE UPDATES – NORMAL OPERATIONS, MAINTENANCE, EMERGENCY

Inadequate revision of procedures has led to problems during PU implementation as documented in the INPO Power Uprate and Cycle Extension Database. A thorough review of all procedures that may be impacted by PU must be completed prior to PU implementation and the affected procedures must be revised accordingly. Procedures to be reviewed include normal operating, abnormal operating (including emergency), surveillance, and PM procedures.

One process for ensuring that all impacted procedures are identified and reviewed is to:

a) Develop a list of all systems, components and operating parameters that will be changed by PU and use it to determine the procedures that require revision.

b) Updates and changes must be identified to ensure that procedures accurately reflect plant status through transitional stages of the project. Therefore, a process should be established to ensure that other changes made during this interim period are adequately assessed by the PU project.

c) Fully involve Operations and Maintenance in this review to ensure that all procedures requiring revision are identified.

6.4 POWER ASCENSION TESTING AND MONITORING

6.4.1 BWROG REVIEWS

During the BWROG reviews of lessons learned [Ref. 7.4e], eleven power uprate ascension test reports were examined for common test issue categories and common elements within the issue categories. As a result of this review, only the pressure regulator test was found to be a common test issue category in three of the eleven reports. However, there were no common elements within this issue category (i.e. the specific equipment challenges precipitating the subject issue category differed for all three plants). This observation, in conjunction with the finding that no other common test issues were identified, suggests that testing results are dependent on the unique equipment characteristics of the individual plants.

6.4.2 OE RECOMMENDATIONS

a) Recommendations are provided below based on the consolidated power uprate start-up testing results as contributed by multiple organizations. They represent strong recommendations and best practices for a successful ramp up to full uprated power levels.

b) <u>Startup Test Matrix</u> - A detailed startup-testing matrix should be developed identifying the testing to be performed at each power level.

c) <u>Overall Controlling Procedure</u> - One controlling procedure should be written based on the matrix to direct the testing and ensure that all tests are performed in the correct sequence.

d) Qualifications for Test Director - Based on industry experience it is recommended that the PU test director should be a very experienced Senior Reactor Operator and should be experienced in performing control system testing. This is key to successful pressure and feedwater level control testing.

e) 'Power Moves' on Same Shift, Same Crew - Where possible, use of the same shift, same operating crews and data-takers for testing at each power plateau is recommended. This will ensure consistent results.

f) Preparation of Test Procedure - It is recommended that the testing procedure writer be a member of the test team to simplify procedural changes when required.

g) Training - Consider Just In Time (JIT) training on the simulator for engineers and operators involved with the testing.

For BWR implementation, see NEDO 33159 [Ref. 7.4e] for additional information.

6.4.3 BWR Steam Dryer Inspection and Evaluation

GE SIL-644, Rev. 2 (August 30, 2006) [Ref. 7.4a] provides detailed steam dryer inspection recommendations, and recommendations for monitoring the moisture content of the main steam and other reactor system parameters. This SIL is applicable to all BWR steam dryers, not just for BWR plants operating at PU conditions. The BWROG Steam Dryer Integrity Committee developed the original "BWR Moisture Carryover and Operational Response Guidance" that was included in SIL-644, Rev. 1, Appendix D.

GE in conjunction with the Boiling Water Reactor Vessel Internals Project (BWRVIP) has developed steam dryer and inspection guidelines, BWRVIP-139, Steam Dryer Inspection and Flow Evaluation Guidelines [Ref. 7.6a]. This document discusses the different dryer configurations and the relative risk of failure along with analyses of the failure consequences. This document summarizes previous dryer repair history based on a BWR Steam Dryer Operational Experience survey issued by the BWROG. Dryer inspection guidelines, flaw evaluation methods, and operational guidance are also addressed in the inspection guidelines.

BWRVIP-06A, Rev. 1 [Ref. 7.6b], Section 4, has been updated to include recent dryer failures. This document addresses resulting loose parts issues.

BWRVIP-182: BWR Vessel and Internals Project, Guidance for Demonstration of Steam Dryer Integrity for Power Uprate [Ref. 7.6c] provides a resource for planning and managing BWR steam dryer issues for PU.

KEY POINT – For planning and managing BWR steam dryer issues, follow the inspection and monitoring recommendations of GE SIL 644 [Ref. 7.4a] and the BWRVIP-139 steam dryer inspection guidelines [Ref. 7.7a]. Incorporate the generic loose parts evaluation included in Section 4 of BWRVIP-06A [7.6b] in future plant-specific loose parts evaluations.

6.4.4 PLANT BASELINE DATA

To provide a reference for historical pre-PU operation and the effect of PU modifications, plant baseline data should be obtained prior to installing plant modifications needed to support operating at the increased power levels; and immediately after the plant modifications are installed but prior to operating the plant at PU conditions. Basic parameters to be measured for all systems and components expected to be impacted by PU include:

a) Steam, feedwater, recirculation system (BWR), and core flow rates
b) Temperatures
c) Pressures
d) Radiation levels
e) Vibration levels
f) MSL moisture content

PU plant data should be compared with the pre-PU data. For all unexpected increases or increases greater than projected, increased inspection of potentially affected components should be addressed.

KEY POINT: Perform baseline measurements for key parameters expected to be impacted by PU prior to and immediately after making the required plant modifications needed to support operation at the increased power level. PU data should be compared with baseline data, and for unexpected increases above baseline plant data, increased inspection of potentially affected components should be undertaken.

6.5 STARTUP VIBRATION MONITORING

See Section 3.1.2, Appendix E and NRC Reg. Guide 1.20 [Ref. 7.2c]

6.6 THERMAL PERFORMANCE TESTING

The need for a stand-alone thermal performance test is dependent on whether turbine modifications were required to support the PU. If there were turbine modifications, such as an upgrade to the high-pressure turbine, then the thermal performance warranty from the turbine supplier will likely include a specification for a thermal performance test (e.g., modified PTC-6). This testing may be combined with the power ascension test, depending on prerequisite conditions for the two tests. There are no special recommendations for the performance of this test.

7 REFERENCES (listed by INPO, NRC, EPRI, GE, BWRVIP, etc.)

7.1 INSTITUTE OF NUCLEAR POWER OPERATIONS DOCUMENTS

(a) INPO Significant Event Report 5-02, *Lessons Learned from Power Uprates*, August 2002.

(b) INPO 09-005, "Power Uprate Implementation Strategies – A Leadership Perspective," March 2009.

(c) INPO EPG-10, *Inservice Testing Program*, December 2006.

(d) INPO 05-006, *Engineering Organization Success Factors*, December 2005.

(e) INPO SOER 99-1, Loss of Grid, December 1999.

(f) INPO SER2-06 Electromatic Relief Valve Degradation.

(g) INPO 09-003, Excellence in the Management of Design and Operating Margins, February 2009.

7.2 U.S. NUCLEAR REGULATORY COMMISSION DOCUMENTS

(a) NRC RS-001 Revision 1, *Review Standard for Extended Power Uprates*, December 2003.

(b) NRC LIC-109 *Acceptance Review Procedures*, May 2008, ADAMS Accession No.: ML081200811.

(c) NRC Regulatory Guide 1.20, *Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing*, March 2007.

(d) NRC Regulatory Guide 1.174 Rev. 1, *An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*, ML031780764, August 2003.

(e) NRC Regulatory Issue Summary 2002-03: "Guidance on the Content of Measurement Uncertainty Recapture Power Uprate Applications."

(f) NUREG-0800, "USNRC Standard Review Plan."

(g) 10CFR50, Appendix A, General Design Criteria for Nuclear Power Plants.

7.3 Electric Power Research Institute Documents

(a) Technical Report BWRVIP-182, *BWR Vessel and Internals Project, Guidance for Demonstration of Steam Dryer Integrity for Power Uprate*, January 2008, Product ID 1016166.

(b) EPRI Report NSAC-202L-R2, *Recommendations for an Effective Flow-Accelerated Corrosion Program*, April 1999.

(c) EPRI Technical Report BWRVIP-139, *BWR Vessel and Internals Project, Steam Dryer Inspection and Flaw Evaluation Guidelines*, April 2005, Product ID 1011463.

(d) EPRI Technical Report BWRVIP-06-A, *BWR Vessel and Internals Project, Safety Assessment of BWR Reactor Internals*, April 2002, Product ID 1006598.

7.4 GENERAL ELECTRIC COMPANY DOCUMENTS

(a) SIL No. 644 Revision 2, *BWR Steam Dryer Integrity*, August 30, 2006.

(b) “Generic Guidelines for General Electric Boiling Water Reactor Extended Power Uprate", NEDC-32424P-A, Class III (GE Proprietary Information), February 1999 (ELTR-1).

(c) “Generic Evaluations of General Electric Boiling Water Reactor Extended Power Uprate", NEDC-32523P-A, Class III (GE Proprietary Information), February 2000 (ELTR-2) and Supplement 1 Volumes 1 and 2.

(d) “Constant Pressure Power Uprate Licensing Topical Report”, NEDC-33004P-A, Class III (GE Proprietary Information), Revision 4, July 2003.

(e) NEDO-33159, Rev. 2, BWR Owners Group EPU Committee,” Extended Power Uprate (EPU) Lessons Learned and Recommendations,” December 2008.

7.5 FERC RELIABILITY STANDARDS

(http://www.nerc.com/page.php?cid=2|20).

7.6 BWRVIP DOCUMENTS

(a) BWRVIP 139, Rev. -, *Steam Dryer Inspection and Flow Evaluation Guidelines*.

(b) BWRVIP 06A, Rev. 1, *Safety Assessment of BWR Reactor Internals*.

(c) BWRVIP 182, Rev. -, *BWR Vessel and Internals Project, Guidance for Demonstration of Steam Dryer Integrity for Power Uprate*.

8 APPENDICES

Pages

APPENDIX A
ACRONYMS

ACRONYMS, NOMENCLATURE, AND NAMING CONVENTIONS	
AC	Alternating Current
ACRS	Advisory Committee on Reactor Safeguards
AFW	Auxiliary Feedwater
ALARA	As Low As Reasonably Achievable
ASLB	Atomic Safety and Licensing Board
AST	Alternate Source Term
ATWS	Anticipated Transient Without SCRAM
BOP	Balance of Plant
BTRS	Boron Thermal Regeneration System
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
BWRVIP	Boiling Water Reactor Vessel Internals Project
CCWS	Component Cooling Water System
CD	Condensate
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CLTP	Current Licensed thermal Power
COLR	Core Operating Limits Report
CPPU	Constant Pressure Power Uprate
CVCS	Chemical and Volume Control System
DBE	Design Basis Event
DC	Direct Current
DNB	Departure from Nucleate Boiling
ECCS	Emergency Core Cooling System
ECW	Essential Cooling Water
EDG	Emergency Diesel Generator
ELTR	Extended (Power Uprate) Licensing Topical Report
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EPU	Extended Power Uprate
ERV	Electromatic Relief Valve
ESW	Emergency Service Water
FAC	Flow Accelerated Corrosion
FAT	Factory Acceptance Testing
FERC	Federal Energy Regulatory Commission
FIV	Flow Induced Vibration
FME	Foreign Material Exclusion
FMEA	Failure Modes and Effects Analysis
FR	Federal Register

ACRONYMS, NOMENCLATURE, AND NAMING CONVENTIONS	
FW	Feedwater
FWBP	Feedwater Booster Pump
FWH	Feedwater Heater
GDC	General Design Criteria
GE	General Electric
GEHNE	General Electric Hitachi Nuclear Energy
GOTHIC	Thermal-hydraulic analysis program authored by Numerical Applications, Inc.
HD	Heater Drain
HP	High Pressure
HVAC	Heating, Ventilation, and Air Conditioning
INPO	Institute of Nuclear Power Operations
ISTS	Improved Standard Technical Specifications
JIT	Just In Time
LAR	License Amendment Request
LERF	Large Early Release Frequency
LOCA	Loss of Coolant Accident
LOFT	Loss of Fluid Test
LP	Low Pressure
LR	License Renewal
LVDT	Linear Variable Displacement Transformer
MCC	Motor Control Center
MELLLA	Maximum Extended Load Line Limit Analysis
MISO	Midwest Independent System Operator
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSL	Main Steam Line
MSR	Moisture Separator Reheater
MSSV	Main Steam Safety Valve
MUR	Measurement Uncertainty Recapture
MWe	Megawatts Electric
N-1	Naming convention for refueling outage just prior to the power uprate outage
N-2	Naming convention for refueling outage two cycles prior to full uprate
NEI	Nuclear Energy Institute
NEPA	National Environmental Protection Agency
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OE	Operating Experience
OECD	Organization for Economic Cooperation and Development
OLTP	Original Licensed Thermal Power
PJM	PJM Interconnection, a regional transmission organization
PM	Preventive Maintenance
POC	Point of Contact
PRA	Probabilistic Risk Analysis

ACRONYMS, NOMENCLATURE, AND NAMING CONVENTIONS	
PU	Power Uprate
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RCB	Reactor Containment Building
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RESAR	Westinghouse Reload Analysis
RG	Regulatory Guide
RHR	Residual Heat Removal
RIS	Regulatory Issue Summary
RR	Reactor Recirculation
SAR	Safety Analysis Report
SAT	Site Acceptance Testing
SECY	Formal issue papers issued by NRC Office Directors to the Commission
SER	Safety Evaluation Report
SER	Significant Event Report
SFP	Spent Fuel Pool
SIL	Service Information Letter
SIS	Safety Injection System
SOER	Significant Operating Event Report
SPU	Stretch Power Uprate
SRLR	Supplemental Reload Licensing Report
SRP	Standard Review Plan
SRV	Safety Relief Valve
SSC	Structures, Systems, & Components
SSV	Secondary (Side) Safety Valve
SWCS	Service Water Cooling System
TBS	Turbine Bypass System
TGB	Turbine Generator Building
TS	Technical Specifications
UFM	Ultrasonic Flow Meter
UFSAR	Update Final Safety Analysis Report
VAR	Volt-Ampere Reactive

APPENDIX B
ORGANIZATIONAL GUIDELINES

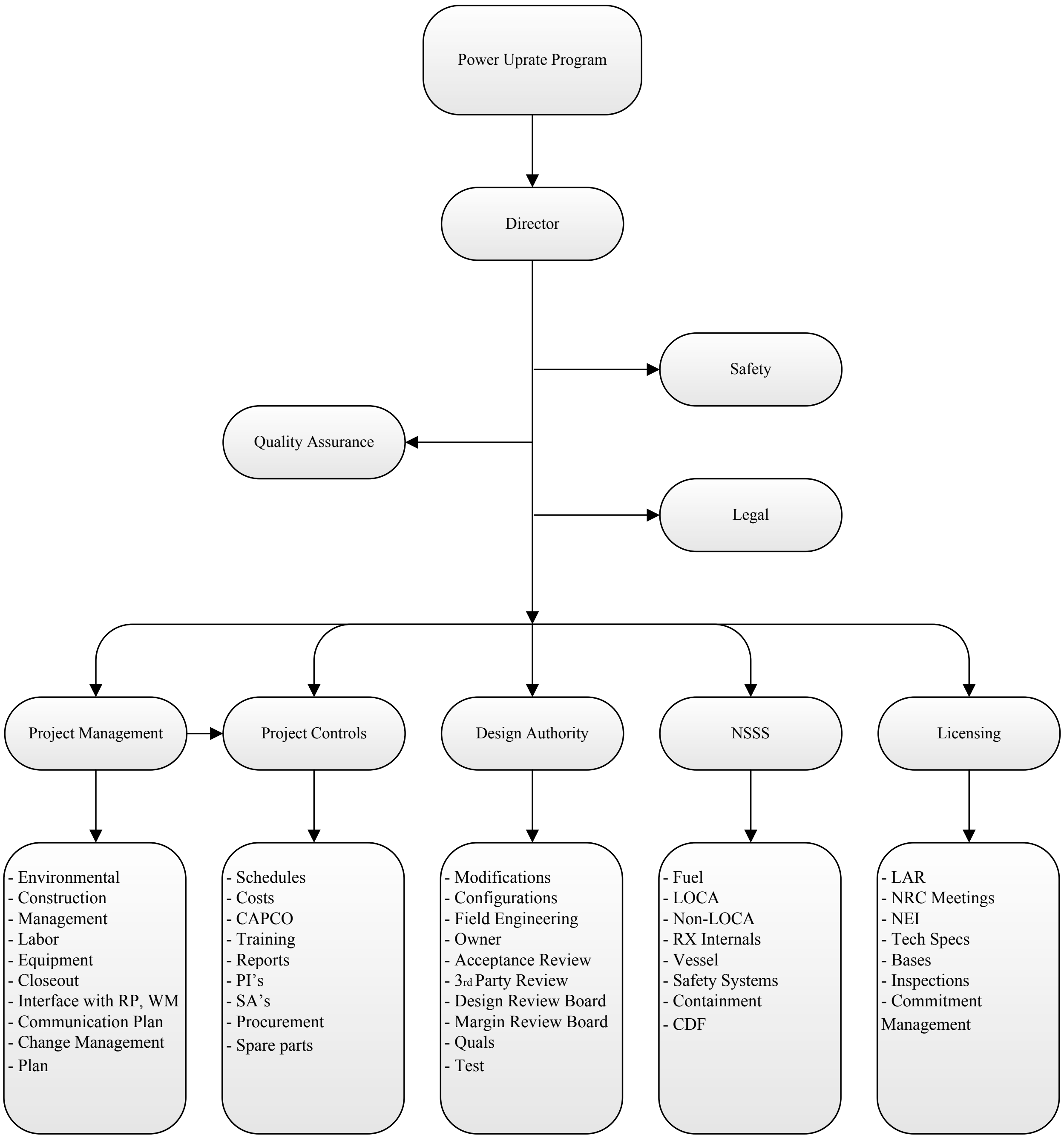


Fig. B.1: Example Organization Chart No. 1

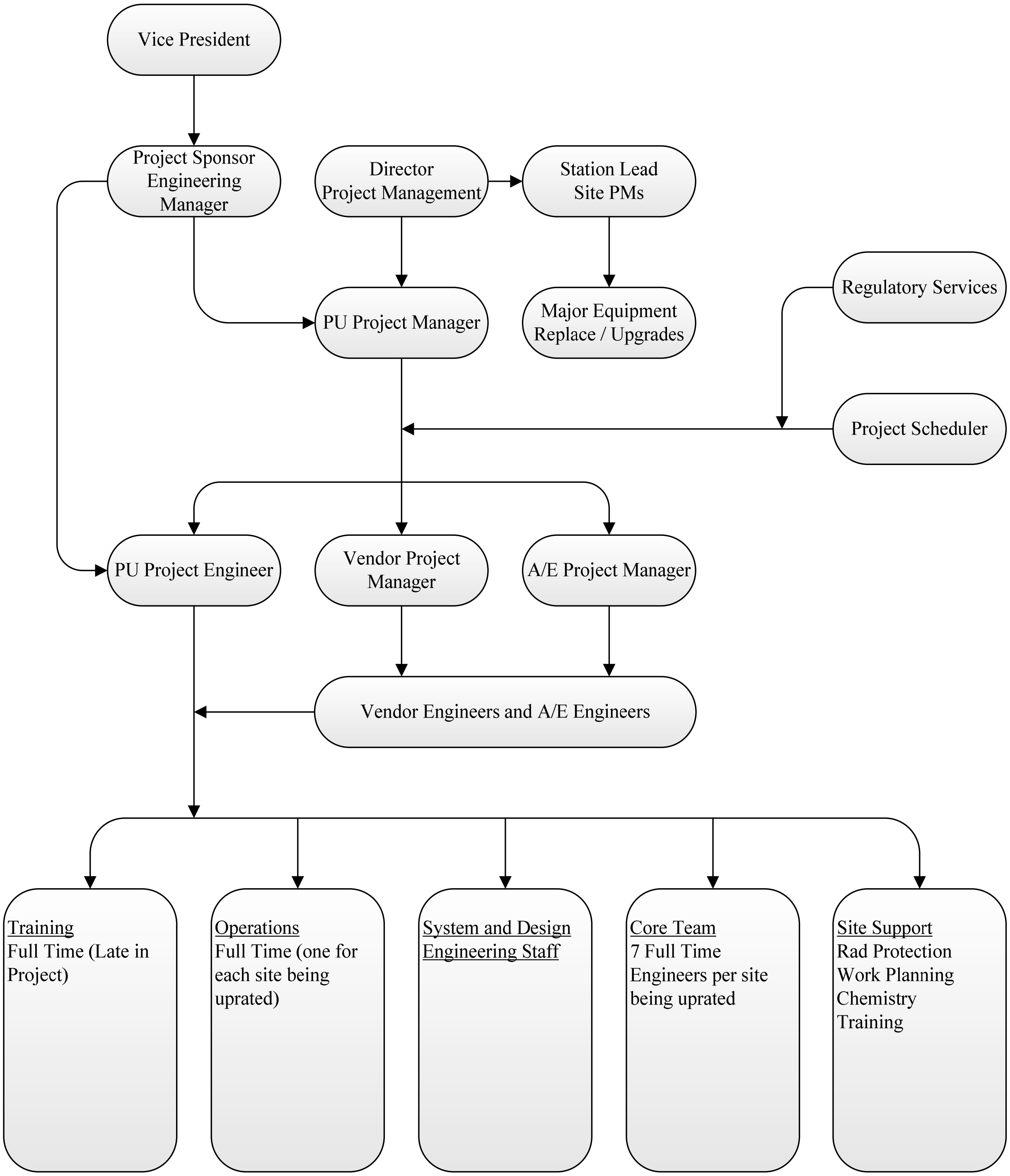
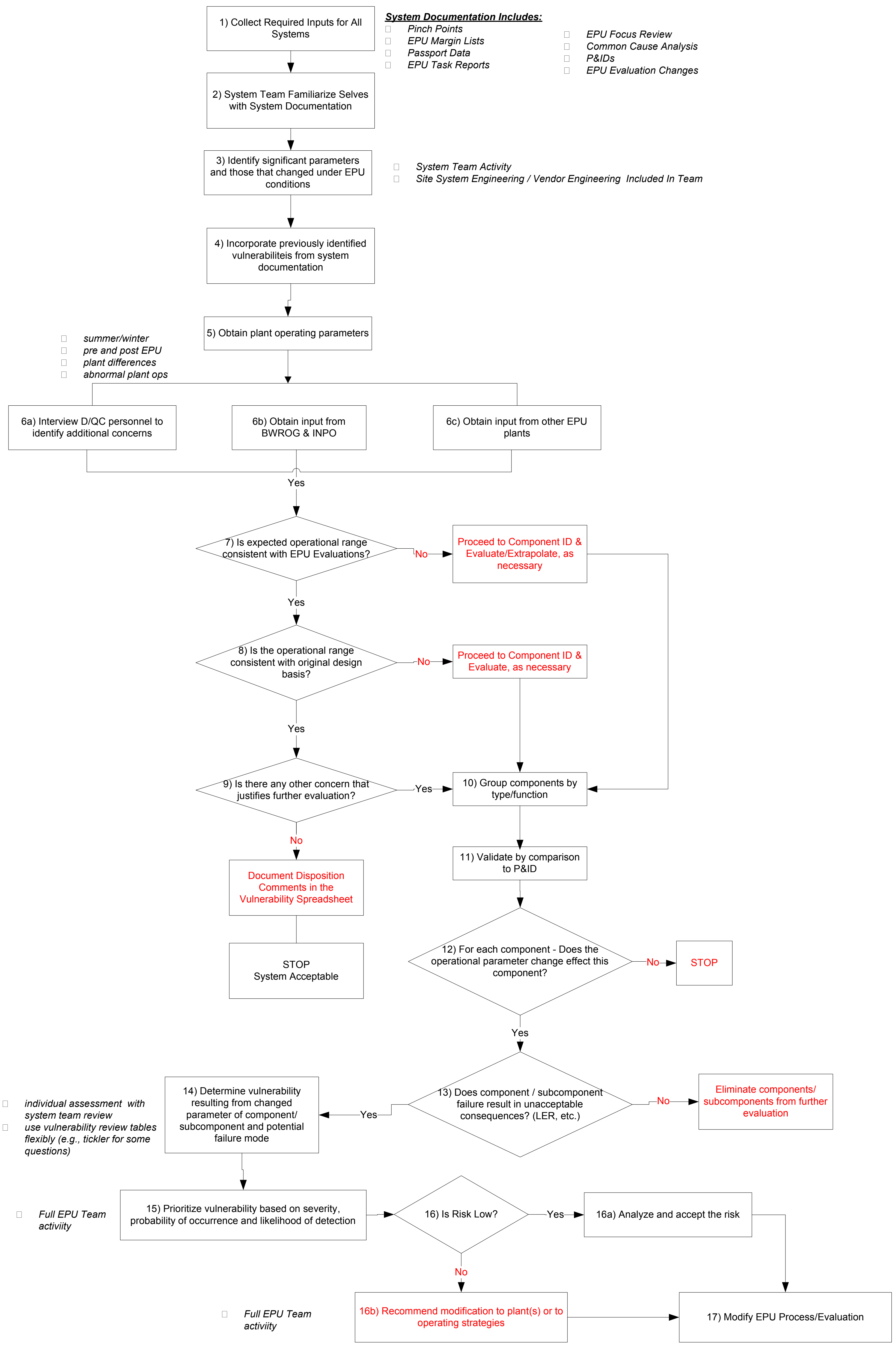


Fig. B.2: Example Organization Chart No. 2

APPENDIX C
SYSTEM AND COMPONENT VULNERABILITY REVIEW PROCESS

C.1: System and Component Vulnerability Review Process Diagram



APPENDIX D
ANALYSIS DETAILS

This appendix provides a general discussion of the typical analysis considerations and PU impact found for various systems and components. This is not considered to be an all inclusive list nor is it a 'cookbook' for performing PU analyses. It does however, provide the flavor of information gathered and lessons learned from previous power uprate projects, and may provide some 'heads up' considerations for future projects.

D1 NSSS

Nuclear Steam Supply System evaluations necessitate the verification that each installed system component and the associated analyses are in compliance with the design codes, standards and criteria for the revised nominal operating conditions. In some instances it will be necessary to revise the documented analyses to account for the increased power level. Three levels of effort may be necessary to accomplish this review as detailed below:

a) No Change to Design Duty - The first level is to identify for which NSSS system and associated component where no change in the original design basis and functional requirements are required. For those components and/or systems, no additional effort is required with respect to the uprating.

b) New Duty is Bounded by Existing Design - The second level of effort is to identify the NSSS components where the uprated conditions are bounded by analysis performed for a generic design or for a plant with the identical systems component at power levels equal to or greater than those associated with the proposed change. For these cases, an evaluation is provided to document the acceptability of the installed system or component.

c) New Supporting Analysis - The third level of effort is to confirm compliance with the applicable design codes, standards and criteria for specific instances where the uprated conditions are not bounded by analysis performed for a generic design or for a unit with the identical components at duty ratings equal to or greater than those associated with the proposed change.

Major NSSS components such as the reactor vessel (or rector pressure vessel), pressurizer, and steam generators will always require detailed analysis for changes under PU (i.e., neutron fluence, thermal and mechanical fatigue, usage factor, overpressure protection, etc.) In addition, analysis is typically organized by systems and programs. Affected systems and some details of the required evaluations/analyses are included here.

D1.1 Reactor Coolant System – PWR

Analyses will be required to determine the pressurizer spray, power operated relief and safety valve relief capacity necessary to maintain the original design basis at the increased power level. The specific plant Safety Analysis Report discusses the design basis for that unit. Evaluations will be required to determine the necessary operating range of the RCS control, protection and measurement instrumentation (e.g. pressure, temperature, flow, level, flux mapping, and nuclear power) and the associated systems (e.g. nuclear instrumentation, flux mapping, bottom mounted instrumentation and incore thermocouple systems) at the increased power level. Any necessary revisions to the current operating ranges or functional requirements will be identified.

D1.2 Chemical and Volume Control System (CVCS) (PWR)

All functional requirements will be reviewed. The areas most likely impacted will be:

a) CVCS Heat Load – If the uprating results in an increased RCS cold leg temperature, the heat loads from the CVCS heat exchanger to the component cooling water system will increase.

b) Letdown Component Ratings – If the RCS hot leg temperature is increased, the uprated functional requirements may not be enveloped by the current component design bases. The capability of the components to perform at the uprated conditions will be confirmed and appropriate modifications made.

D1.3 Residual Heat Removal System (RHR) (PWR)

A higher power level results in increased decay heat being generated in the core during normal cool down, refueling operations, and accident conditions. This will result in a higher heat load on the residual heat exchangers during the cool down and also during the refueling outage. The increased heat loads will be transferred to the Component Cooling Water System (CCWS) and ultimately to the Service Water Cooling System (SWCS). It will be necessary to evaluate the performance of the RHR, CCWS, and SWCS with the increased heat loads.

On some plants, the RHR system pumps and heat exchangers are an integral part of the Safety Injection System (SIS). For these plants, the ability of the RHR to meet the design and functional requirements of the SIS at the uprated conditions will be confirmed.

D1.4 Safety Injection System (PWR)

The required volume, duration and heat rejection capability of the safety injection flow in the event of a break is determined based on analytical and empirical models which simulate reactor conditions subsequent to the postulated RCS and steam system breaks. As a result of these analyses the system and component requirements necessary to demonstrate compliance with regulatory requirements at the uprated power level will be established. Should the requirements fall outside the bounds of the installed system, it may be necessary to implement software/hardware modifications, provide revised heat rejection rate data for the CCWS and revise the electrical loading of the SIS equipment on the safeguards for electrical systems. In the event the current SIS provides adequate safety margin, no additional effort would be required.

D1.5 Boron Thermal Regeneration System (BTRS) (PWR)

Evaluations at PU conditions will be performed to assure that the installed system/component design bases and functional requirements bound the proposed operating conditions.

D1.6 Standby Liquid control (SLC) System (BWR)

Evaluation at PU conditions will be performed to assure the installed system/component design basis and functional requirements bound the proposed operating conditions. System modifications or a higher boron concentration is typically required for EPU.

D2 TURBINE CYCLE

D2.1 Main Steam System

Evaluation of the Main Steam (MS) piping and supports are performed for vibration as a result of increased steam mass and velocity and erosion related issues.

Evaluation are required of the MSSVs at PU conditions to ensure that they will open in the desired sequence and discharge the steam from the Steam Generators (or RV) following reactor trip in the event the pressure in the Main Steam system up to the Main Steam Isolation Valve exceeds the MSSVs setpoints.

Evaluation of the Main Steam Isolation Valve (MSIV) closure time during the reactor trip or the Turbine Trip is required to ensure that the closure time meets the desired closure time required by the accident analysis.

Other evaluations include a review of check valve slam loading for design basis transients or turbine stop valve (TSV) closure transient loading of piping and supports.

D2.2 High and Low Pressure Turbines and Related Systems

The High Pressure (HP) Turbine Rotor may not be capable of passing the steam flow required for the uprated condition. This may result in modifications to the rotating blade flowpath, fixed blade flow path, or Nozzle Blocks for the EPU loading conditions. More typically, a complete retrofit of the HP steam flow path is affected for EPU projects.

An evaluation will also be performed on the Low Pressure (LP) Turbine steam flow path to determine its capability of passing the PU steam flow. Typically, modern retrofit LP cylinders are adequately designed for steam conditions up to and including those experienced under EPU. In some cases, EPU may dictate retrofit of one or more stages or replacement of the LP turbines in its entirety. It should be noted that if LP retrofit is planned ahead of future PU programs, the retrofit vendor should be required to provide LP evaluations for both current and uprated conditions. In particular, the vendor should provide assurance that the design has been analyzed and has adequate margin for operation under EPU (e.g., in terms of (a) blade and root attachment stresses, (b) overspeed, (c) rotodynamic stability, (d) flutter, etc.)

Correspondingly, evaluations are required on related piping and controls systems to evaluate the impact of the PU and determine required modifications. In particular, careful attention should be given to the cross-around relief valves and piping to ensure adequate flow capacity at PU and any planned interim operating points.

D2.3 Main Generator and Related Components

An evaluation of the generator and related components such as bearings, bushings, generator cooling, generator winding, etc of the impact of the PU is required.

D2.4 Moisture Separator Reheaters (MSR)

The MSR and related systems are evaluated for adequacy to handle PU steam flow and drains. Existing MSRs may or may not be adequate to support performance at the uprated condition and may require either recertification or modification for PU.

D2.5 Main Feed Pump (Turbine Driven or Motor Driven)

The Main FW Pump is evaluated to determine if it can properly accommodate the demands for the new aggregate FW flow resulting from the PU. Modifications may be required to the pump or related electrical and control systems as a result of the PU. Additional attention should be taken to evaluate the drain and drain lines to ensure sufficient capacity exists for PU operation.

D2.6 Condensate System

The condensate pumps may be inadequate to pump the required volume of condensate with enough head for the PU. The condensate pump is evaluated and modifications may be required to the pump, the pump motor, and the electrical power source. The condensate system piping is evaluated for adequate capacity.

D2.7 Feedwater Heaters (FWH) and Heater Drains (HD)

An evaluation of the impact on the FWHs for PU conditions is required. Based on past experience, it is possible that existing FWHs will not be adequate to support performance at the PU condition and will require modifications. Correspondingly, the HD capacities are evaluated to ensure that there is adequate capacity to accommodate the increased drain volume from the FWH. The drain valve size may be inadequate to handle the increased drain volume and will require replacement.

D2.8 Feedwater Booster Pumps (FWBP) (PWR)

The FWBP may be inadequate to pump required volume of the FW with enough head for the PU. The FWBP is evaluated and modifications may be required to the pump impeller, the pump, the pump motor, and the electrical power source.

D2.9 Main Condenser

An evaluation of the main condenser and related systems is performed for the increased EPU steam flow from the main turbine. The evaluation shall determine the capacity of the condenser to condense the rejected volume of steam for the uprated condition at the time of uprate implementation. Vibration analysis of condenser tubes under increased steam loading is also considered.

D3.0 SUPPORTING SYSTEMS

D3.1 Auxiliary Feedwater (AFW) Pumps (Motor or Turbine Driven) (PWR)

The PU may require increased volume of the AFW to remove the core decay heat to bring the plant from Mode 3 to Mode 4. The AFW pump, motor and turbine need to be evaluated to determine their capability to supply the required AFW flow to the Steam Generators.

D3.2 Auxiliary Feedwater Storage Tank (PWR)

An evaluation of the AFW storage tank volume for adequacy to mitigate the design basis event including Appendix R fire hazards scenario is required. The PU may require increased AFW flow to the Steam Generator to cool down the plant in the station blackout scenario.

D3.3 Spent Fuel Pool (SFP) Cooling System

The SFP cooling system requires evaluation to determine its capability to remove the decay heat from the spent fuel post power uprate implementation.

D3.4 Component Cooling Water (CCW) System

The CCW system needs to be evaluated to ensure that there is adequate margin to reject plant heat in design basis event.

D3.5 Essential Cooling Water (ECW) / Emergency Service Water (ESW) / Safety Related Service Water System

An evaluation of the ESW system is required to determine and document the capability of the system to remove the heat rejected by the plant during the design basis event.

D3.6 Essential Cooling Water / Ultimate Heat Sink (River, Lake, Ocean, Pond, Tower)

An evaluation of the ECW / ESW source is required to confirm adequate heat removal capability for the PU during all seasons and for all design basis events. The evaluation shall document that the water source (e.g., river, lake, and ocean) is capable of removing heat from the plant during the hottest period of the year as discussed in the Updated Final Safety Analysis Report (UFSAR).

D3.7 Emergency Diesel Generator (EDG)

The EDG load is expected to have nominal increase resulting from the power uprate. An evaluation is required to evaluate the adequacy of the ED setpoints to ensure that they are adequate to support the plant uprated condition and the EDG demand.

D3.8 Electrical Systems

Evaluations are made of all plant electrical systems to confirm that they are adequate to support plant PU conditions. This will include safety and non-safety related switchgears, circuit breakers, fuse lists, cables, Motor Control Centers (MCC), etc.; Transformers including Main Transformers; Isophase Bus Duct and cooling. The review will include thermal loading associated with current flow under PU and short circuit duty.

D3.9 Turbine Bypass System (Steam Dump)

The Turbine Bypass System (TBS) capacity to accommodate the design basis load rejection at PU conditions will be evaluated. Based on past experience, it is possible that the steam dump will not be adequate for the PU, and modifications to the steam dump valves or control system may be required to meet the design basis plant load rejection capability. (Plants have various bypass capacity)

D3.10 Containment Cooling System (Water System)

The containment cooling water system shall be evaluated to insure that the heat load change in the containment heat load as a result of the PU is within the design capability of the containment cooling water system (note: some plants do not have a chilled water system).

D3.11 Heating, Ventilating, and Air Conditioning (HVAC) Systems

The Reactor Containment Building (RCB) HVAC is expected to have an increased RCB heat load as a result of the PU condition and will require evaluation.

Main Control Room HVAC system should be evaluated for potential changes to the post accident heat load as a result of PU.

D3.12 Reactor Containment Building

RCB will require evaluation for the revised PU RCB temperature and pressure conditions during the considered spectrum of UFSAR Design Basis Events (DBE).

D3.13 Turbine Generator Building (TGB)

An evaluation of the TGB structure will be required for the increased loading for any replacement major components such as HP Turbine, LP Turbines, Generator, MSRs, etc. This would include building vibration analysis to insure that the rotating equipment and the building resonant frequencies do not coincide with each other, as this could lead to continuous building vibration and fatigue failure of the building structures.

D4 ACCIDENT ANALYSES, PLANT PROGRAMS, ETC.

D4.1 Flood Protection

Plant flood protection design should be evaluated for potential impact from significant increases in fluid volume of tanks and vessels.

D4.2 Radwaste Systems (Liquid, Gaseous)

Evaluate the impact to the plant waste systems from increases in RCS fission products and liquid and gas volume. Modification is typically not required although higher duty of resins may require more frequent backflush. Resin replacement intervals may also shorten with PU.

D4.3 Protection Against Postulated Piping Failures in Fluid Systems Outside Containment

PU may impact environmental conditions including control room habitability or access to areas important to safe control of post accident operations and these potential changes must be evaluated. Older pre–SRP plants should plan on additional analysis to justify PU operating conditions.

D4.4 Safety Analysis – Chapter 15

Design basis information must be collected and reviewed to ensure that the uprating safety evaluation will be based on the actual fuel and core components in the plant, the actual plant operating history, and any plant system changes associated with the uprating. The review includes the utility requirements, core design parameters, safety criteria and related constraints, specific operating limitations and past operating history. This initial review will identify the objectives, requirements and constraints for the uprated cycle being designed.

The design process ensures that the utility power and energy requirements established in the PU design review phase are achieved. The key safety parameters for the cycle (i.e. uprating and reload parameters) are then determined based on the preliminary design.

As an example, the PWR safety bases to be met for the uprated core are:

Departure from Nucleate Boiling Design Basis – There will be at least a 95 percent probability that Departure from Nucleate Boiling (DNB) will not occur on the limiting fuel rods during normal operation, operational transients, or during any transient conditions arising from faults of moderate frequency (Condition I and II events), at a 95 percent confidence level. In order to meet this basis, the minimum allowable DNB ratio is determined. This minimum allowable DNBR depends upon the DNB correlation employed in the analysis.

Fuel Temperature Design Basis – During modes of operation associated with Condition I and Condition II events, there is at least a 95 percent probability that the peak kw/ft fuel rods will not exceed the UO2 melting temperature, at the 95 percent confidence level. The melting temperature of UO2 is taken as 5080 degrees F, unirradiated and decreasing 58 degrees F per 10,000 MWD/MTU. By precluding UO2 melting, the fuel geometry is preserved and possible adverse effects of molten UO2 on the cladding are eliminated. To preclude center melting and to provide a basis for overpower protection system setpoints a calculated centerline fuel temperature of 4700 degrees F has conservatively been selected as the overpower limit.

a) *Reactor Coolant System Pressure* – Peak RCS pressure is not to exceed 110 percent of the design pressure during Condition I and Condition II events.

b) *Loss of Coolant Design Bases (10CFR50.46*) - The Loss of Coolant Accident (LOCA) design bases incorporates a review of peak cladding temperature, maximum cladding oxidation, maximum hydrogen generation, coolable geometry and long-term cooling.

Compliance with these bases ensures that the margin of safety as defined in the basis of the technical specification has not been reduced (a 10CFR50.59 requirement). These design bases are interpreted as safety limits for the safety evaluation.

The objective of the uprating safety evaluation is to verify compliance with the currently established safety limits for the specific unit with the uprated core and plant system design. This is accomplished by examining each accident presented in the FSAR or subsequent submittals to the NRC to determine if the reference analysis remains valid for the uprating. The specific transients for each plant can be found in the unit's Safety Analysis Report. For those accidents which are affected by the uprating, an evaluation is performed to verify compliance with the applicable safety limits.

In the performance of an uprating safety evaluation, each accident is examined and the bounding values of the key safety parameters which could be affected by the uprating are determined based on the reference analysis. These parameters form the basis for determining whether the reference safety analysis remains valid. For an uprating, values of these safety parameters are determined for the core during the nuclear, thermal and hydraulic, and fuel rod design process. Each of these parameters is compared with the reference analysis value to determine if any parameter is not bounded. If all of the parameters are bounded, the reference analysis remains valid and no new analysis is needed to verify that the safety limits are not exceeded. Should one or more of the safety parameters not be bounded, a re-evaluation of the accident is performed.

The re-evaluation may be of two types. If the parameter is only slightly out of bounds, or if the transient is relatively insensitive to that parameter, a simple quantitative evaluation may be made. Alternatively, should the deviation be large or be expected to have a more significant or not easily quantifiable effect on the accident, a re-analysis of the accident is performed. If the accident is re-analyzed, the analysis methods follow standard procedures and will typically employ analytical methods which have been used in previous submittals to the NRC. These methods are those which have been presented in the FSAR or subsequent submittals to the NRC for that plant, reference SARs such as RESAR, or reports submitted for NRC approval. The re-analyzed accident must continue to meet the appropriate safety limit for that event in order to be considered to have acceptable results.

Accident re-analysis may also be necessary if there are any changes made to the reactor plant systems, either in configuration, performance or setpoints as determined during the PU design review phase. Should any plant or system changes affecting safety be incorporated, their impact will be determined during the evaluation.

D5 BOP/NSSS INTERFACE REQUIREMENTS

Key Point – Design interfaces between the NSSS and BOP are key to the success of the power uprate and need to be identified and included in the project integrated schedule.

Following are some examples of interfacing systems that may need evaluation and/or modification to support the increased electrical power output from the power uprate.

a) Alternating Current (AC) and Direct Current (DC) Emergency Power Systems – The plant is equipped with both onsite (AC and DC) and offsite (AC) emergency electrical power systems to provide reliable power to the NSSS and BOP safety systems. Increases in the electrical power requirements of the NSSS essential systems, which result from the uprating will be identified.

b) AC and DC Power Systems – The plant is equipped with electrical power systems which supply the NSSS equipment. Any increased NSSS electrical loads which may be required as a result of the uprating will be identified.

c) Auxiliary Feedwater System (PWR) – Increased duty in term of either flow delivery or backpressure will be identified as system interface requirements.

d) Mass and Energy Release to the Containment – The mass/energy release data will be employed to determine the containment pressure and temperature environment during the postulated accidents and to determine the associated loadings on the structures and components within the containment in accordance with the licensing basis of the specific unit.

e) Main Feedwater – Runout flow from the FW system following MSLB and prior to isolation will impact containment and fuel accident response analyses. The flow delivery capability of the modified power train pumps systems under EPU will potentially increase relative to assumptions used in current accident analyses.

f) Main Steam System – The primary purpose of the steam system is to contain and transport steam from the NSSS steam generators to the main turbine. The adequacy of the installed relief capacity (e.g., Main Steam Safety Valves) will be determined and identified to the project team.

g) Component Cooling Water System (CCWS) – The CCWS ensures that leakage of radioactivity from the components being cooled is contained within the plant. Revised heat rejection rates and/or cooling water flow requirements will be identified.

h) Radiological Source Terms – Radiological Source Terms are used in assessing the radiological consequences of accidents. Any changes identified as a result of uprated parameters will be identified.

i) Plant Testing – Numerous qualification and performance tests were completed for the initial startup to assure that all systems/components of the BOP and NSSS are in compliance with the design and licensing bases for the unit. These tests also establish the operating margins of the plant systems. It will be necessary to verify that the performance of any system/component modifications is in compliance with the requirements of the uprating and the licensing bases. The recommended test program for NSSS and interfacing BOP systems would be developed on a plant specific basis, depending upon the magnitude of hardware modifications and the magnitude of the uprating.

APPENDIX E
RESPONSIBILITIES FOR VIBRATION MONITORING PROGRAM

E1 INTRODUCTION

Flow Induced Vibration (FIV) has resulted in several instances of fatigue failures of plant components following power uprate. These types of failures can lead directly to unit trip, and have in special circumstances resulted in loss of uprate production for extended periods. The nature of these failures or incidents is varied, and includes:

- Steam dryer failure with generation of loose parts
- ERV actuator structural failure
- Isolated phase bus duct internals failures with attendant unit trip
- Equipment drain root valve piping attachment failure with attendant forced shutdown
- FW system in-line probe failures
- Unit trip on MSL low pressure trip signal due in part to variation in signal due to vibration

Due to the varied nature of potential vibration issues, and the importance of learning from industry experience, it is recommended that PU programs appoint a vibration program coordinator from the start of the project. The resources needed to fully address potential vibration issues are varied in terms of organizations, expertise, and physical work location. These include areas such as upfront analytical support (NSSS, BOP, and specialty), licensing, operations, training, monitoring/testing, startup, and data acquisition/analysis. This coordinator will be expected to marshal, organize, and manage the necessary resources for the duration of the project to ensure that to the extent possible, vibration issues will be anticipated and addressed as part of PU evaluations, startup, and monitoring.

E2 PROGRAM COORINDATOR

The coordinator of the vibration monitoring program is to be responsible for development and maintenance of the overall program. The program can be based on similar efforts for new plant startup (e.g., using ASME OM-S/G-2003, Part 3). Activities are expected to include:

a) Engineered Vibration Monitoring Programs – This effort will typically include planned monitoring of steam dryer (BWR), MS piping, FW piping, Reactor Recirculation system (RR) (BWR), and Residual Heat Removal (RHR) piping using temporary test instrumentation (accelerometers, strain gauges, LVDTs), or hand held instrumentation. Acceptance criteria should be established in advance of the monitoring activities.
b) Rotating Equipment – Monitoring should include main turbine, generator, exciter, feedwater pump and feedwater pump turbine, condensate pump, RR pumps (BWR), Reactor Coolant Pumps (PWR), motor / generator sets (BWR). Acceptance criteria should be established in advance of the monitoring activities.

c) Other Vulnerabilities – The Vibration Program should review other station vulnerabilities based on station and industry operating experience.

d) Training and Operations Support – The coordinator should work with the station training department to ensure that site operations and maintenance personnel are aware of the importance of vibration issues, and to use this resource as the 'eyes and ears' for vigilant observations relative to emergent vibration issues following PU.

e) Startup Support - Outage and startup testing preparation by engineering, maintenance, and training departments. Input to startup test plan.

f) Acceptance - Vibration monitoring and acceptance during power ascension testing (coordinate resources, etc.)

g) Analysis - Analysis of data acquired during start-up and reconciled with baseline data obtained prior to EPU implementation.

h) Regulatory Submittals – Coordinating the preparation of submittals related to confirmatory data acquisition and analysis (e.g., steam dryer info to NRC)

E3.0 INTERFACE WITH OTHER LEADS

The Vibration Coordinator will be expected to work closely with the Licensing Manager and Startup Test Manager to maximize the potential for a seamless licensing and startup and vibration monitoring test program.

KEY POINT – Confirmatory licensing submittals related to vibration monitoring results following power ascension testing should be drafted (or outlined in detail) well in advance of the testing and data collection. This will help to ensure that all involved organizations are keenly aware of the intended information to be provided in the submittal and that all parts of the submittal are being supported by the program that is in place.

APPENDIX F
EMERGENT ISSUES RESPONSE GUIDELINE

The following description and flow chart contains the basic steps used to perform the process when new issues are identified that would benefit by industry involvement

1. Plant identifies an issue that needs to be resolved either during preparation of EPU license submittal or other phase of EPU including Implementation and testing.
    - 1.1. Review the EPRI and INPO lessons learned databases to determine if others have identified and resolved the same or similar problem.
    - 1.2. If YES, then determine if previous resolutions are sufficient for the current issue.
        - 1.2.1. If YES, then use resolution and exit this process after adding the current issue to the EPRI database as another example of the issue.
        - 1.2.2. If NO, then continue to Step 2.
    - 1.3. If NO, then continue with Step 2.
2. Determine if the issue has potentially generic implications. Is it likely that another plant could have the same issue? Doe the issue represent a potential common system, component or reactor type problem? If uncertain then continue by assuming that it is generic.
    - 2.1. If YES, then continue with Step 3.
    - 2.2. If NO, then resolve for your plant, enter into the EPRI database and exit this process
3. Contact NEI POC to set up a call with appropriate Task force representatives to discuss resolution possibilities.
    - 3.1. NEI POC will contact appropriate Task force personnel and set up conference call as soon as possible after notification. The type of issue and time required for resolution will determine the urgency needed in establishing the conference.
    - 3.2. Task Force will discuss the issue and determine the path to resolution based on the remaining steps in the flow chart.
4. Conduct the Task Force call and determine next Steps.
    - 4.1. Determine if there is regulatory impact as defined by examples below:
        - Issue has potential to delay submittal of license amendment request
        - Issue was raised through an RAI with no clear resolution path.
        - Issue appears to conflict with previous resolutions to generic technical items.

4.1.1. If YES, then assemble regulatory response sub team to handle communications with the NRC on resolution path being pursued.

4.1.1.1. Go to STEP 4.2

4.1.2. If NO, then go to Step 4.2

4.2. Determine if external technical resources are required or desired to formulate the resolution.

4.2.1. If YES, then go to Step 4.3 to select resource path.

4.2.2. IF NO, then go to Step 4.4.

4.3. Determine best resource for issue resolution based on the following filters:

4.3.1. IF BWR specific issue then refer to the BWROG – PIRT process and potential creation of special committee to resolve.

4.3.2. If PWR specific issue then refer to the PWR owners group for resolution

4.3.3. If best path is to choose lead plant for resolution, obtain plant commitment from desired lead plant to continue with resolution.

4.3.3.1. Determine if work will be out sourced, or performed by the lead plant internal resources.

4.3.3.2. Go to Step 4.5

4.4. Initiating plant will resolve issue and provide final resolution information back to the Task Force. Issue will be updated in the EPRI database with resolution.

4.5. Produce scoping document for outsourcing work providing details for deliverables, schedule required and Contacts for the industry.

4.6. Document final results and distribute to NEI Task Force.

4.7. Add to or update the EPRI Power Uprate database with final resolution, ensuring that contact for questions is included.

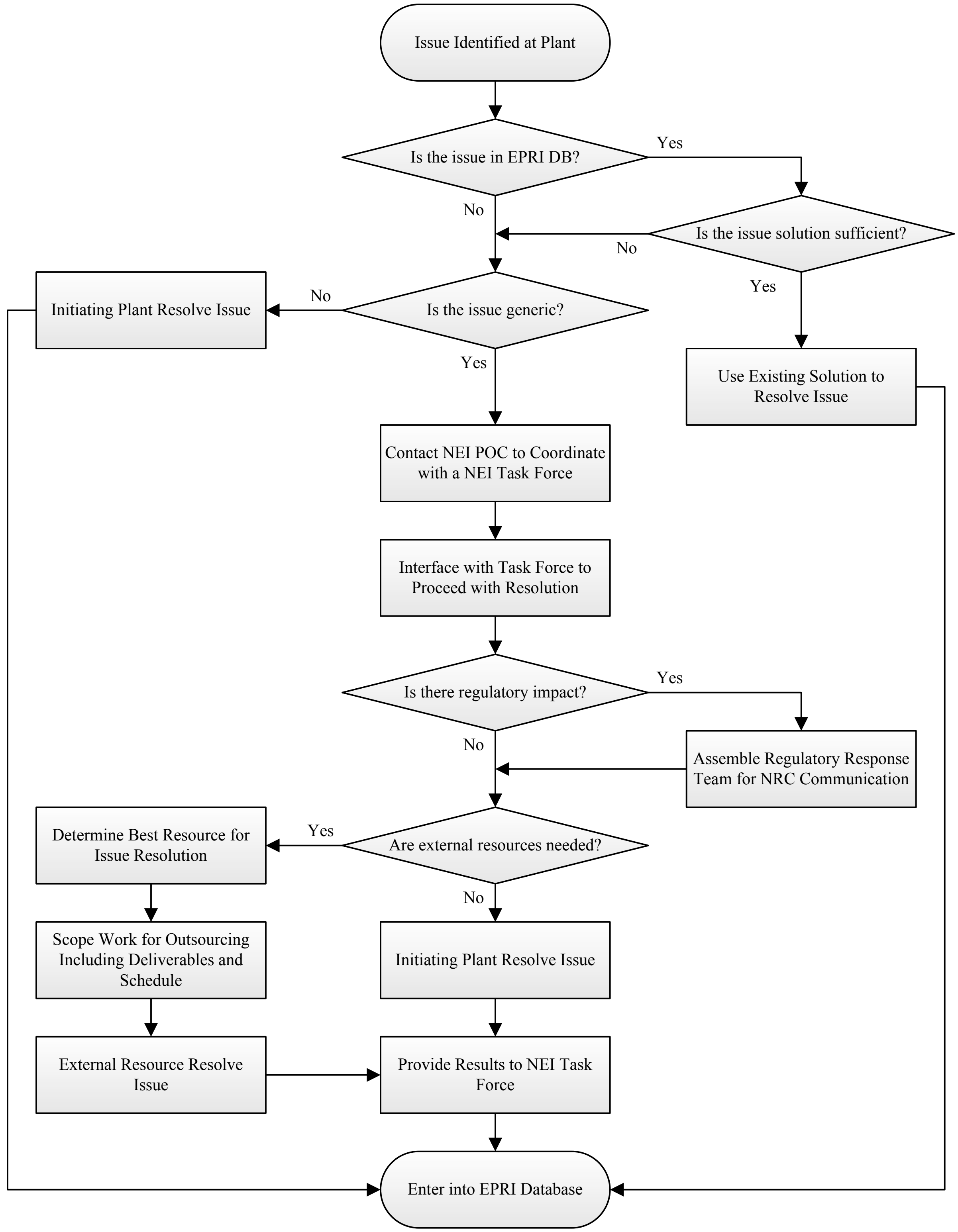


Fig. F.1: Emergent Issues Flow Chart

APPENDIX G
EPRI LESSONS LEARNED DATABASE

Several events have occurred as a result of inadequate analysis, design, or implementation of plant power uprates. Many of the events involved equipment damage, unanticipated responses to plant conditions, or challenges for operating staff.

One method to improve the power uprate process is to share lessons between utilities to prevent similar events for recurring.

In 2007 EPRI developed a vehicle that would allow utilities to share additional lessons learned during the power uprate process that were not captured by the INPO Power Event Database process. Additional power uprate events that were not necessarily significant enough to be documented via the INPO Power Event Database were collected by EPRI and incorporated into the EPRI Power Uprate Database. The Power Uprate Database is a continuation of efforts by EPRI to better provide power plant professionals with lessons learned and best practices in power uprates.

The Power Uprate Database is designed to be a resource of issues and lessons learned encountered and the resolutions of those issues. Once they are in the system, members can search the issues by keywords and filter the search results by plant type, component, and/or system. Utilities are also expected to add lessons learned as they are experienced while implementing a power uprate.

The EPRI Power Uprate data base is intended to be used by utilities that are implementing or considering implementing power uprate projects. Utilities should consider utilizing the EPRI Power Uprate data base for the following;

- View and/or download prior industry lessons learned so these events can be analyzed for applicability
- Entering lessons learned via the “Add An Issue” feature during the power uprate process to share recent lessons learned with other utilities

Power Uprate Database can be accessed from EPRI.com by the following link:

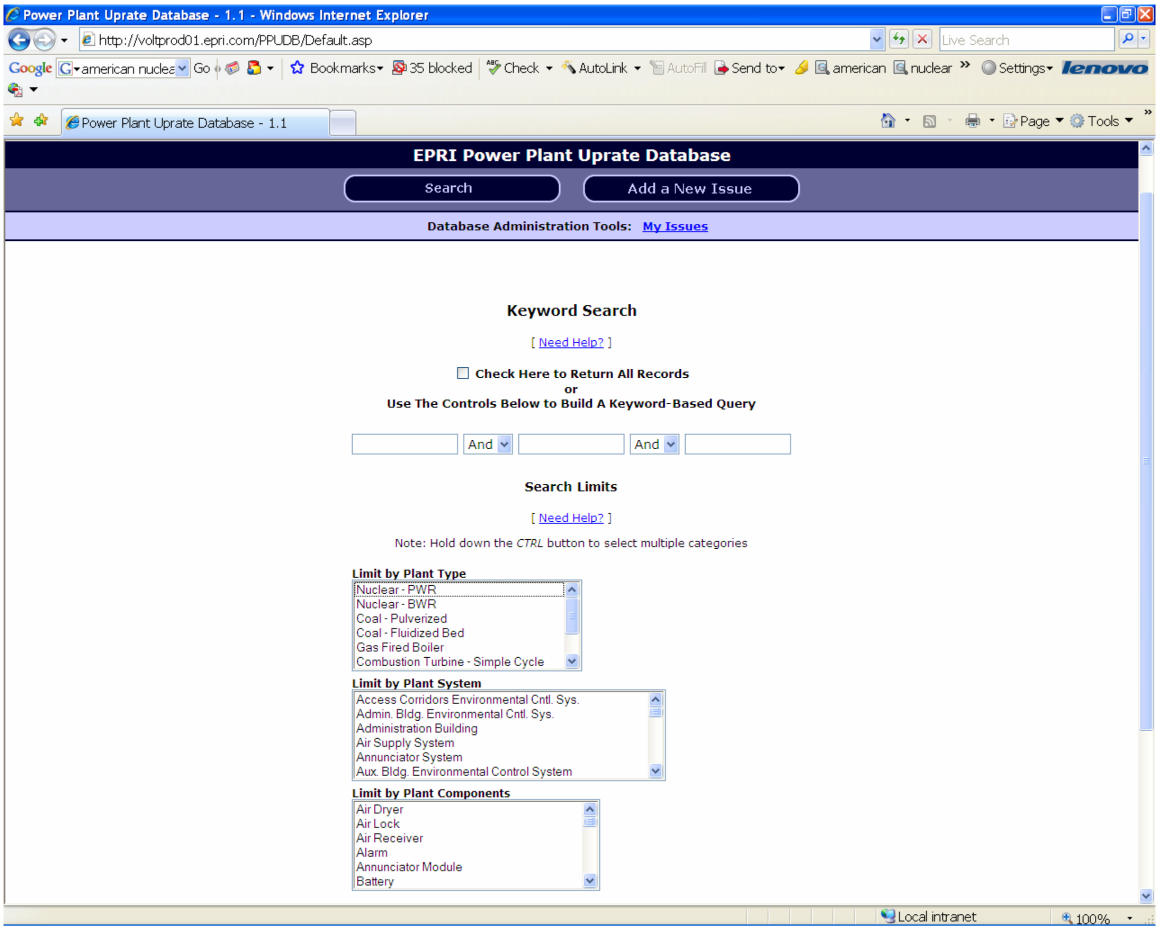
http://ppudb.epri.com/Default.asp

Initial Power Uprate Database Development

- Initial EPRI Power Uprate Database input information was provided from the INPO web site (132 items) and from a power uprate A/E (73 items) for an initial data base total entry count of 205. The INPO Plant Events Database is created by INPO from utility events extracted from Nuclear Network OEs, LERs, and NRC PNOs. Significant power uprate events are categorized by INPO and are entered into the INPO Power Event Database.
- All EPRI NMAC members were notified that they could access data base, search, copy and download information.
- Utilities can add items with no special approvals, however to modify or delete others items requires “special access” (privileged users status)

- The entire data base can be downloaded by anyone to Excel for further data sorting or analysis

Below is the opening screen of the EPRI Power Uprate Database. From this screen, one can either perform a key word "Search", "Add a New Issue" or "Check Here to Return All Records".



Key features provided by this data base are:

- An option on the search screen to records from all keywords.
- Search results filters by Plant Type, Plant Systems, and/or Component.
- The ability for users to edit the issues that they added to the database
- Export capability for search results
- Integrated User Management for Administrators

Computer Requirements

Browser
The Power Uprate Database takes advantage of features only available in newer Web browsers. Internet Explorer 6 or higher is recommended. Netscape Navigator 8.1 or higher is supported, also.

Script
The Power Uprate Database requires that Cookies and JavaScript are enabled on your browser.

Searching the System

The Power Uprate Database can be searched by entering keywords into the fields of the "Search" page. Originally, up to 3 keywords, one per field, could be entered, along with the "qualifier" drop-down lists of "And" or "Or". The number of results to be returned per page is determined by the "Results Per Page" drop-down list. This capability still exists and has been enhanced by the ability to return all keywords and to filter results by Plant Type, Plant System, or Component. Please refer to the following examples in using the various search features.

Search Example: Returning All Records
Returning the entire database for browsing is easy. Click on the checkbox labeled "Check Here to Return All Keywords" and then execute the search.

Search Example: Keyword Search
Entering "rotor" in the first text field, and selecting the drop-down "And," then entering "blade" in the second text field will return all issues with the words rotor and blade. Entering "rotor" and selecting the drop-down "Or" and entering "blade" will return all issues with either the words "rotor" or "blade".

Search Example: Advanced Keyword Search
The Power Uprate Database offers the ability to search on up to three keywords and a corresponding combination of logical possibilities. To build on the last example, Entering "rotor" in the first text field, and selecting the drop-down "And," then entering "blade" in the second text field will return all issues with the words rotor and blade. To add to this, selecting "Or" in the second drop-down and entering "weld" into the third text field will return all issues with the both words "rotor" and "blade" or any issue with the word "weld" in it. If the dropdown values are swapped ("rotor" OR "blade" AND "weld"), then the search results will yield all issues with both words "blade" and "weld" or any issue with the word "rotor" in it.

Search Example: Filtering Search Results
The filters can be used to focus a broader search. For example, if you wanted to return all of the records associated with Nuclear Power plants, click on the checkbox labeled "Check Here to Return All Keywords" and then select "Nuclear - PWR" and "Nuclear - BWR" from the "Limit by Plant Type" list.

Adding/Editing an Issue

To add a new issue to the Power Uprate Database, use the form on the "Add an Issue" page. Issues must have a resolution in order to be accepted.

Version 1.1 of the PPUDB allows users to edit their own issues. To see a list of issues associated with your username, click on "My Issues". Users are allowed to edit their own issues; but only administrators can delete issues.

The following data fields are provided

Required data fields:

Title - A concise title to the issue.

Issue Event Date - The date the issue occurred.

Date Submitted - Automatically entered by the system.

Issue - A brief description of the issue or problem encountered. There is an 8000 character limit on this field to ensure that the description is brief.

Solution and Lessons Learned - A brief description of the solution to the problem. There is also an 8000 character limit on this field.

Contact Information - Contact name, company, phone, and e-mail address are required.

Optional additional fields that can be used are:

Plant Type- This dropdown is used to specify the plant type associated with this issue. The default value is "[No Plant Type Selected]". Users are encouraged to specify the Plant Type as people searching the database will use this when they restrict searches by filters. Only one value can be selected

Plant Name - The name of the plant associated with issue.

Utility Name - The name of the utility associated with issue.

Affected Components - The components which are associated with this issue Multiple Selections are allowed.

Affected Systems - The plant systems which are associated with this issue. Multiple Selections are allowed.

Notes - Additional notes relating to the issue. There is an 8000 character limit on this field.

References - Additional references relating to the issue. There is a 2000 character limit on this field.

Related Links - Up to 5 URL's relating to the issue can be added.

To add the issue, to the system click the "Add Issue to Database without Attachment" button. To add an attachment to the issue, click the "Add Issue and Add an Attachment" button.

Adding an Attachment

To add an attachment, enter a title for the file you want to attach, and then click the "Browse" button to search your hard drive for the file. Click the "Add Attachment to Database" button. Currently accepted file types are Microsoft Word (.doc), Microsoft Excel (.xls), Adobe Acrobat (.pdf), Rich Text Format (.rtf), Zip Archives (.zip), and Plain Text (.txt). Uploads are currently limited to files that are under 2 Megabytes in size.
Once you have finished adding attachments, click the "Finished Adding Attachments" button.

Exporting Results

The PPUDB uses an HTML table to enable exporting of search results. After running a search, click on the "Export Results" button to bring up the Export Results screen, and follow the directions before the table.

Below is an example of the fields provided by the “Add An Issue” page:

ADD AN ISSUE

Please complete the form below to enter a new issue into the database. Note that required items are marked with an asterisk (*).

[Need Help?]

Reset Form	Note: Clicking the "Reset Form" button resets ALL input fields
*** Title:**	
*** Issue Event Date:**	- (MM/DD/YYYY)
*** Date Submitted:**	6/12/2008
Plant Type	[No Plant Type Selected]
Plant Name	
Utility Name	

Associated Components (Hold down the CTRL key to make multiple selections)	Air Dryer Air Lock Air Receiver Alarm Annunciator Module Battery

Associated Systems (Hold down the CTRL key to make multiple selections)	Access Corridors Environmental Cntl. Sys. Admin. Bldg. Environmental Cntl. Sys. Administration Building Air Supply System Annunciator System Aux. Bldg. Environmental Control System

*** Issue - (8000 Character Limit - Why?)**

*** Solution and Lessons Learned - (8000 Character Limit - Why?)**

Notes - (2000 Character Limit - Why?)

References - (2000 Character Limit)

Related Links

Link 1:
Link 2:
Link 3:
Link 4:
Link 5:

*** Contact Name:**	
*** Company:**	Electric Pow er Research Inst
*** Phone:**	
*** E-mail:**	

Add Issue To Database w ithout Attachment

Or

Add Issue and Add an Attachment