THE SYSTEM 80+ TM STANDARD PLANT DESIGN REDUCES OPERATIONS AND MAINTENANCE COSTS

Deva R. Chari and James E. Robertson
ABB Combustion Engineering Nuclear Systems,
a business unit of Combustion Engineering, Inc., U.S.A.

ABSTRACT

To be cost-competitive, nuclear power plants must maximize plant availability and minimize operations and maintenance (O&M) costs. A plant whose design supports these goals will generate more power at less cost and thereby have a lower unit generating cost.

The ABB Combustion Engineering Nuclear Systems (ABB-CE) System 80+TM Standard Nuclear Power Plant, rated at 1400 megawatts electric (MWe), is designed for high availability at reduced cost. To demonstrate that the duration of refueling outages, the major contributor to plant unavailability, can be shortened, ABB-CE developed a detailed plan that shows a System 80+ plant can safely perform a refueling and maintenance outage in 18 days. This is a significant reduction from the average current U.S. plant outages of 45 days, and is possible due to a two-part outage strategy:

Use System 80+ advanced system design features and relaxed technical specification (TS) time limits to shift some maintenance from outages to operating periods: and

Use System 80+ structural, system, and component features, such as the larger operating floor, permanent pool seal, integral reactor head area cable tray system and missile shield, and longer life reactor coolant pump seals, to reduce the scope and duration of outage maintenance activities.

Plant staffing level is the major variable, or controllable contributor to operations costs. ABB-CE worked with the Institute of Nuclear Power Operations (INPO) to perform detailed staffing analyses that show a System 80+ plant can be operated reliably with 30 percent less staff than currently operating nuclear plants of similar size.

Safety was not sacrificed when ABB-CE developed the System 80+ refueling outage plan and staffing level. The outage plan was developed utilizing a defense-in-depth concept for shutdown safety. The defense in-depth concept is implemented via systematic control of outage risk evaluation (SCORE) cards. The SCORE cards identify primary and alternate means of satisfying critical safety functions during all phases of the outage. Shutdown defense-in-depth is a major contributor to the System 80+ shutdown core damage frequency of 8.4E-07 events per year, a factor of 50 better than current plants.

1.0 INTRODUCTION

To be cost competitive, nuclear power plants must maximize availability factors and minimize operation and maintenance costs. Historically, about 75 percent of the unavailability of U.S. nuclear plants has been due to scheduled refueling and maintenance outages, and 25 percent to unscheduled, or forced, outages. The greatest potential for availability gains, therefore, exists in improving the planning and execution of scheduled outages. Trends in the nuclear industry towards longer fuel cycles and shorter outages have dramatically improved availability in the last decade.

To further improve on industry accomplishments, advanced light water reactors (ALWRs) have been designed for even quicker, safer refueling and maintenance outages. Using requirements developed during the Electric Power Research Institute (EPRI) Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD) program, ABB Combustion Engineering Nuclear Systems (ABB-CE) designed the System 80+™ Standard Plant with features that will support shorter outages, while increasing the level of safety.

ABB-CE then developed a refueling outage plan for the System 80+ design that integrates an 18-day outage schedule with a safe shutdown protection plan. The summary integrated schedule shows plant operating modes, mechanical and electrical division outages, and major refueling and maintenance windows. The safe shutdown protection plan utilizes a concept of defense-in-depth to minimize vulnerabilities that may result from abnormal plant conditions encountered during shutdown operations, such as reduced inventory operations, abnormal electrical power lineups, and inoperable safety systems. Shutdown defense-in-depth is maintained during the refueling outage by ensuring that sufficient systems and components are available to maintain the following safety functions:

- Decay Heat Removal,
- Water Inventory Control,
- Maintenance of Vital Auxiliaries (AC and DC power),
- Reactivity Control, and
- Containment Integrity.

Multiple methods for maintenance of these safety functions are assured by the use of systematic control of outage risk evolutions (SCORE) cards. The SCORE cards identify redundant means of satisfying safety functions for each plant mode and condition during the outage.

Plant staffing level is the major variable, or controllable contributor to O&M costs, accounting for about 21 percent of total production costs in plants with ABB-CE nuclear steam supply systems for the period from 1991 to 1995.

This paper includes:

- a summary description of the design features that contribute to higher availability and lower operations and maintenance costs;
- the System 80+ 18-day refueling outage schedule, including its justification;
- the safe shutdown protection plan for maintaining defense-in-depth for critical safety functions;
- the time windows available to perform necessary major equipment maintenance;
- and, a summary of the System 80+ staffing analysis.

2.0 SYSTEM 80+ SUMMARY DESIGN DESCRIPTION

The System 80+ Standard Plant Design is an ALWR design with a rating of 1400 megawatts electric (MWe). It received Final Design Approval (FDA) from the U.S. Nuclear Regulatory Commission in July 1994, and Design Certification in May 1997. Design Certification allows a purchaser to apply for a single Combined Operating License (COL) under the conditions of the Code of Federal Regulations, Title 10, Part 52 (10 CFR 52). Detailed descriptions of the System 80+ Standard Plant Design are presented in References 1 and 2. The design incorporates several improvements to meet the requirements of industry and regulatory groups for ALWRs, including features for increased redundancy and diversity of safety systems, and for improved maintainability. Both are top-tier goals of the EPRI ALWR URD. A System 80+ plant will achieve higher availability at reduced O&M cost, largely due to new and improved design features.

2.1 Features that Permit On-Line Maintenance and Increased Shutdown Safety

The System 80+ Standard Plant Design includes several advanced design features that increase safety system redundancy and diversity. The added system and component redundancy, combined with risk-based insights, permits relaxation of echnical pecifications times during normal operation at power. This provides greater time windows to perform selected maintenance activities with the plant on line, thereby reducing the refueling outage maintenance scope and duration. The net effect is a reduction in outage time and increase in plant availability. The added redundancy increases the number of safety systems and components that maintain critical safety functions when the plant is shut down, enhancing the plant's shutdown defense-in-depth. The advanced design features that provide the greatest benefit to plant availability and shutdown safety are:

- Safety related fluid systems with four 100 percent capacity trains:
  - Containment spray and shutdown cooling systems with interchangeable pumps,
  - Emergency feedwater system,
  - Component cooling water system,
  - Station service water system, and
  - Essential chilled water system.
- Electrical distribution system improvements:
  - Alternate AC generator that can be substituted for an emergency diesel generator,
  - An additional unit auxiliary transformer,
  - An additional reserve auxiliary (startup) transformer,
  - Main transformer backfeed capability (from the grid to the plant),
  - Four 4160 volt AC safety buses, and
  - Six vital batteries.

These features and their benefits to safety are described more fully in Reference 3.

The Nuplex 80+™ Advanced Control Complex allows much of the instrumentation and controls systems testing, formerly done during outages, to be performed with the plant on-line. Nuplex 80+ systems conduct continuous on-line self testing and failure identification. Operator modules and maintenance panels provide displays that identify most failures down to the instrument module level. The result is that fewer failures remain latent, so troubleshooting and repair can be completed while the plant is on-line.

2.2 Features that Improve Maintainability During Outages

The System 80+ Standard Plant Design incorporates many architectural, structural, system and component features for easier maintenance. Some of the design improvements that will shorten refueling outages are:

Access space and walkways - The arrangement of buildings allows more efficient movement of personnel and equipment. A large enclosed equipment staging area outside the containment equipment hatch provides a staging area to support outage activities in the containment. Access to the reactor building operating floor can be gained through either the personnel airlock or the equipment hatch.

Jib cranes - Jib cranes are strategically located within the reactor building to perform various light load handling tasks. This allows the polar crane to be dedicated to lifting heavy loads which are generally part of critical path activities and avoids reliance on the polar crane for light loads. The jib cranes also allow movement of loads away from the reactor while fuel assemblies are being handled.

Permanent platforms - The containment arrangement includes open platforms made of deck grating, instead of closed concrete floors, in most locations. The result is that permanent platforms exist in most areas adjacent to equipment. Stairways provide access to most of the platforms, so the erection and removal of temporary scaffolding is not required during the outage.

Head Area Cable Tray System (HACTS) with Integral Missile Shield - The HACTS allows simultaneous removal and replacement of all control element drive mechanism (CEDM) and heated junction thermocouple (HJTC) cabling in the reactor head area. Integration of the missile shield into the HACTS eliminates the need for a separate missile shield. Currently operating plants require 10 to 12 hours of critical path time for removal of separate missile shields.

Permanent refueling pool seal - The permanent pool seal eliminates the need to handle and install a large, heavy pool seal assembly to seal the annulus between the reactor vessel flange and the refueling pool floor prior to flooding the refueling canal.

Higher integrity fuel - System 80+ utilizes the same high integrity ABB-CE fuel used in current operating plants. For 1996, all plants with ABB-CE fuel exceeded the Institute of Nuclear Power Operations' (INPO) fuel reliability index. The absence of fuel failures reduces outage radiation levels and contamination due to fission products. Thus, lengthy purification of the reactor coolant system (RCS) is avoided early in the outage, and less decontamination of the refueling pool is required near the end.

Fewer elements that become activated corrosion products - Proper selection of materials minimizes the use of elements that become activated corrosion products as they pass through the core, such as cobalt and antimony. The reduction in activated products reduces outage radiation levels and contamination.

SG improved access: larger manways and hand holes - The manways on the primary and secondary sides of the System 80+ steam generators are 53 cm (21 inches) () in diameter, providing easier access than the 46 cm (16 to 18 inch) () manways on the earlier steam generators. The larger manways allow faster installation of nozzles dams and SG tube inspection equipment. Two 20cm (8 inch) diameter hand holes are provided on the SG secondary side, aligned with the tube lanes, for faster secondary side inspection and cleaning.

Longer life RCP seals - The shaft seals for the System 80+ reactor coolant pumps have an improved design that extends their design life to 48 months. A System 80+ plant will operate on an 18 to 24 month fuel cycle, so only two seal assemblies must be replaced during each outage, effectively cutting in half the resources required for seal replacement.

Improved SG tube material - The System 80+ steam generator tubes are fabricated from Iconel-690, which has been shown in both laboratory testing and in plant experience to have much greater resistance to corrosion than the Alloy 600 used in most current steam generators. The expected result of the introduction of Iconel-690 is that less SG tube inspection, maintenance and repair will be required during refueling outages.

100 percent multiple stud tensioner - The multiple stud tensioner allows the detensioning or tensioning of all the reactor vessel studs at one time. In addition, the multiple stud tensioner allows the simultaneous removal of all the reactor vessel studs from the work area to the storage area without additional stud handling and reliance on the polar crane.

Bottom mounted in-core instrumentation - The bottom mounted instrumentation design allows the withdrawal and insertion of the instrumentation in parallel with the reactor vessel head disassembly and reassembly operations rather than in series, as is the case with top mounted instrumentation.

Penetration sleeve quick opening closure - The fuel transfer system closure design incorporates slide locks rather than bolts to permit the rapid, simultaneous unlocking and locking of all the fasteners by one person. A dedicated small hoist unit located directly above the closure allows the immediate removal of the closure from the penetration sleeve in the event the polar crane is not readily available. Pre-operational checkouts of the fuel transfer system can proceed immediately upon removal of the closure.

Control Element Assembly (CEA) removal and reinstallation - The CEAs are removed from the fuel assemblies in parallel with the removal of the upper guide structure (UGS) from the reactor vessel. This operation eliminates the time-consuming handling and exchange of CEAs during fuel handling. The CEAs are re-installed into the core during the re-installation of the UGS.

Large laydown Areas - The arrangement of buildings includes large laydown areas to facilitate maintenance activities.

3.0 THE SYSTEM 80+ REFUELING OUTAGE PLAN

The System 80+ refueling outage plan consists of: (1) an 18-day refueling outage schedule and (2) a safe shutdown protection plan. These two integral parts ensure that refueling outages for a System 80+ plant will be performed quickly, efficiently and safely. The development of the refueling outage schedule and the safe shutdown protection plan are discussed in the following sections.

3.1 18-Day Refueling Outage Schedule

The System 80+ Standard Plant Design supports a regular refueling and maintenance outage in 18 days (Figure 1).

An 18 day refueling outage for a System 80+ Standard Plant is possible for two reasons:

- With the plant at power (on line), maintenance is performed where possible without compromising safety, as discussed in Section 3.1.1; and
- With the plant shutdown for refueling and maintenance, the plant design features discussed in Section 2.2 are fully utilized to reduce outage time.

3.1.1Performing On-Line Maintenance

The current generation of operating nuclear plants is often prohibited from placing safety systems in an inoperable status to perform maintenance while the plant is on line. The two major reasons are:

- Technical Specification (TS) requirements for system availability limit the allowable outage times, and
- There is limited redundancy and diversity of backup systems.

During operation at power, plant Technical Specifications usually require safety systems to be fully operable and allow relatively short outage times to return inoperable systems to service. These outage times are often too short to complete required preventive maintenance. For example, emergency diesel generators (EDGs) typically have TS inoperability limits of 3 to 7 days, but regular preventive maintenance on the diesels requires 9 or 10 days. Plants must therefore schedule EDG maintenance during refueling outages, when the TS requirements are less restrictive.

To allow relaxation of Technical Specifications for several systems and components during normal operation, the advanced design features of the System 80+ Standard Plant described in Section 2.1 were combined with the introduction of risk-based insights. Table 1 shows that a System 80+ Standard Plant has much longer allowable outage times in which the utility can perform maintenance during normal operation, without impacting plant safety. Maintenance on-line reduces the refueling outage duration.

Table 1 Comparison Of Technical Specification Outage Times

System/Component Placed Inoperable for Maintenance (System 80 or Palo Verde nomenclature in parentheses)	Allowed LCO Outage Time in Modes 1, 2, 3	
	System 80[1]	System 80+™
1 Containment Spray Pump	72 hours	Indefinite[2]
1 Shutdown Cooling (Low Pressure Safety Injection) Pump	72 hours	Indefinite[3]
1 Emergency (Auxiliary) Feedwater Pump	72 hours	7 days
2 Emergency (Auxiliary) Feedwater Pumps	6 hours	72 hours
1 Component (Essential) Cooling Water Pump	72 hours	Indefinite
1 Station Service Water (Essential Spray Pond) Pump	72 hours	Indefinite
1 Essential Chill Water Pump	72 hours	Indefinite
1 Emergency Diesel Generator	72 hours	14 days
1 Class 1E DC subsystem/channel, including battery, charger, and DC bus	2 hours	72 hours

(1) As built at the Palo Verde Nuclear Generating Station.

(2) If the shutdown cooling pump in the same Division is OPERABLE.

(3) Unless substituting for a Containment Spray pump.

3.1.2Comparison of System 80+ and Current Plant Outage Duration

To ensure that the 18-day System 80+ refueling outage schedule is realistic and achievable, ABB-CE compared the System 80+ schedule with the duration for major outage activities at operating plants. Table 2 shows the best times achieved at any plant with an ABB-CE pressurized water reactor, and the predicted duration for a System 80+ Standard Plant. As shown in the table, the System 80+ and operating plant outage duration are consistent. Time reductions have been taken only if there is a reasonable justification, as indicated in the Discussion column.

Table 2 Refueling Outage Segment Duration (In Hours). For Plants With ABB-CE Pressurized Water Reactors

	Outage Segment (Beginning and Ending Milestones)	*ABB CE Best*	*System 80+*	*Discussion of System 80+ Outage Schedule*
1	Breakers open to Mode 4 (< 350°F)	3	Included in Segment 2	
2	Mode 4 to Mode 5 (< 210°F)	4	32	System 80+ includes 16 hour RCS flush with hydrogen peroxide; some plants with ABB-CE NSSS do not flush.
3	Mode 5 to Mode 6 (RV Head not fully tensioned)	59	40	Faster cooldown--larger capacity SCS Faster mid-loop operation--better instrumentation Faster nozzle dam installation--permanent scaffolding, larger manways
4	Mode 6 Entry to Reactor Head Removal	20	20	Equal to ABB-CE best
5	Head Removal to Begin Core Shuffle	16	16	Equal to ABB-CE best
6	Begin core shuffle to complete core shuffle	96	96	Equal to ABB-CE best
7	Complete Fuel Shuffle/ Reload to RV Head On	24	24	Equal to ABB-CE best
8	RV Head On to Mode 5 (Head Fully Tensioned)	6	6	Equal to ABB-CE best
9	Mode 5 to Begin RCS Fill & Vent	38	70	System 80+ provides time margin for maintenance close-out.
10	Begin RCS Fill & Vent to Mode 4 (> 210°F)	26	40	Faster nozzle dam removal--larger manways
11	Mode 4 to Mode 3 (> 350°F)	6	12	ABB-CE best with allowance for slower heatup
12	Mode 3 to Initial Criticality	34	44	ABB-CE best with allowance for slower heatup
13	Initial Criticality to Mode 1 (> 5% Power)	24	24	Equal to ABB-CE best
14	Mode 1 to Parallel to Grid	3	8	ABB-CE best with allowance for slower power ascension and turbine generator synchronization.
	Composite Total (Hours)	*359*	*432*	
	Composite Total (Days)	*15.0*	*18.0*	

During the outage segments listed above, inspection and maintenance of various plant systems and components are performed. The major outage maintenance areas, and the duration of the "window" when plant conditions permit systems and components to be removed from service, are listed in Table 3.

Table 3 System 80+ Maintenance Activity Windows

System or Component Outage Maintenance Area	*Available Window*	*Basis for Acceptability of the System 80+ Window*
Steam Generators (tube inspection, plugging, staking, sleeving)	10 days	SG Inconel-690 tubes are expected to require less inspection.
Reactor Coolant Pumps (seal replacement)	12.7 days	Improved long life seals require replacement of only 2 sets each outage
Turbine Generator and Systems, Balance of Plant (BOP) Systems	16 days	Not typically critical path activities for current generation plants. Duration is consistent with current operating plants.

3.2 Safe Shutdown Protection Plan - The Shutdown Defense-in-Depth Concept

During a refueling outage, systems, structures, and components important to safety may be unavailable due to plant configuration or conditions. To ensure that the System 80+ Standard Plant provides sufficient systems and equipment to maintain critical safety functions during shutdown operations, ABB-CE developed systematic control of outage risk evolutions (SCORE) cards. (Tables 4 and 5) The SCORE cards identify the primary and alternate means of satisfying safety functions, e.g., decay heat removal, water inventory control, maintenance of vital AC and DC power, reactivity control, and containment integrity, during the entire refueling outage. A SCORE card was developed for each outage schedule period or window to:

- Identify minimum operability requirements for each safety system during each schedule period.
- Identify those sub-systems that are part of the protected equipment, i.e., the minimum set of equipment required to maintain safety functions. These are identified by shaded boxes with a double border in the SCORE cards.
- Identify additional equipment available for use by plant staff for maintaining control of the plant safety functions. These are identified by shaded boxes in the SCORE cards and are available alternatives for maintaining defense-in-depth.
- Identify equipment not available for use. These are identified by not shading in the boxes during maintenance periods when the system or equipment is not available.

Table 4 presents the SCORE card for operating mode 5 with the RCS drained to the centerline of the hot legs. This represents a condition when the risk for loss of critical safety functions is high, so many systems and components are available to achieve defense-in-depth. Table 5 presents the SCORE card for operating mode 6, after refueling activities are complete, risk is lower, and fewer systems and components are required to achieve defense-in-depth.

Table 4 System 80+ Systematic Control of Outage Risk Evolutions (SCORE) Card Mode 5 - Reduced RCS Inventory w/Loops Not Filled (Mid-Loop)

(shaded box)	Available Options
(double-bordered box)	Protected (TS)
(white box)	Out of Service

A. Maintenance of Heat Removal	A	B	C	D	E	F
1. Reactor Coolant System	SG A	SG B	SCS A	SCS B	≥23'	PZR Vent
2. Spent Fuel Pool	SFPCA	SFPCB	≥23'			
B. Maintenance of Inventory	**A**	**B**	**C**	**D**	**E**	**F**
1. RCS Makeup Source	IRWST	BAST	SF Pool			
2. RCS Makeup Flow Path (2 SI req'd)	Charging	SI 1	SI 2	SI 3	SI 4	
3. RCS Inventory Measurement	HJTC wr	HJTC nr	DP wr	DP nr	SCS perf	RCS temp
3. Spent Fuel Pool Makeup Source	BAST	IRWST	RF Pool			
4. Spent Fuel Pool Makeup Flow Path	BAMP	Purif P				
C. Maintenance of Vital AC	**A**	**B**	**C**	**D**	**E**	**F**
1. Power Sources (as req'd)	EDG 1	EDG 2	AAC	UATs	RATs	
2. 4160 VAC Safety Buses (as req'd)	A	B	C	D		
3. 480 VAC Load Centers (as req'd)	A	B	C	D		
4. 120 VAC Vital Distribution Centers (as req'd)	A	B	C	D	1	2
D. Maintenance of Vital DC	**A**	**B**	**C**	**D**	**E**	**F**
1. 125 VDC Class 1E Buses (as req'd)	A	B	C	D	1	2
E. Maintenance of Reactivity	**A**	**B**	**C**	**D**	**E**	**F**
1. Boric Acid Source	IRWST	BAST	SF Pool	RF Pool		
2. Boric Acid Flow Path (2 SI req'd)	Charging	SI 1	SI 2	SI 3	SI 4	BAMP
3. Reactor Trip Circuit Breakers	OPEN			NOT OPEN		
4. Source Range Channels	1	2				
5. Log Power Channels (2 req'd)	A	B	C	D		
F. Containment Integrity	CLOSED			OPEN		

Table 5 System 80+ Systematic Control of Outage Risk Evolutions (SCORE) Card Mode 6 Condition: Level ≥ 23' Above RV Flange (Fuel Move Complete; Div. 1 Maintenance.)

(shaded box)	Available Options
(double-bordered box)	Protected (by Tech Spec)
(white box)	Out of Service

A. Maintenance of Heat Removal	A	B	C	D	E	F
1. Reactor Coolant System	SG A	SG B	SCS A	SCS B	≥23'	PZR Vent
2. Spent Fuel Pool	SFPCA	SFPCB	≥23'			
B. Maintenance of Inventory	**A**	**B**	**C**	**D**	**E**	**F**
1. RCS Makeup Source	IRWST	BAST	SF Pool			
2. RCS Makeup Flow Path	Charging	SI 1	SI 2	SI 3	SI 4	
3. RCS Inventory Measurement	HJTC wr	HJTC nr	DP wr	DP nr	SCS perf	RCS temp
3. Spent Fuel Pool Makeup Source	BAST	IRWST	RF Pool			
4. Spent Fuel Pool Makeup Flow Path	BAMP	Purif P				
C. Maintenance of Vital AC	**A**	**B**	**C**	**D**	**E**	**F**
1. Power Sources (as req'd)	EDG 1	EDG 2	AAC	UATs	RATs	
2. 4160VAC Safety Buses (as req'd)	A	B	C	D		
3. 480 VAC Load Centers (as req'd)	A	B	C	D		
4. 120 VAC Vital Distribution Centers (as req'd)	A	B	C	D	1	2
D. Maintenance of Vital DC	**A**	**B**	**C**	**D**	**E**	**F**
1. 125 VDC Class 1E Buses (as req'd)	A	B	C	D	1	2
E. Maintenance of Reactivity	**A**	**B**	**C**	**D**	**E**	**F**
1. Boric Acid Source	IRWST	BAST	SF Pool	RF Pool		
2. Boric Acid Flow Path	Charging	SI 1	SI 2	SI 3	SI 4	BAMP
3. Reactor Trip Circuit Breakers	OPEN			NOT OPEN		
4. Source Range Channels	1	2				
5. Log Power Channels (as req'd)	A	B	C	D		
F. Containment Integrity	CLOSED			OPEN		

4.0 SYSTEM 80+ PLANT STAFFING ANALYSES

ABB-CE worked with the Institute of Nuclear Power Operations (INPO) to develop the required System 80+ staffing level. The staffing level is based on work processes developed using INPO's Principles and Objectives for the Standard Operation and Support of Nuclear Plants. The staffing requirements developed address the normal expected workload of power plant operation and maintenance.

Since organization and staffing are directly related to, and dependent on, the work processes used at a power plant, INPO facilitated the development of standardized work processes for plant construction, start-up, and operations. A computerized staffing analysis mathematical model was developed by INPO to expedite performance of work process activities manipulations. The model supports rapid process analysis, including sensitivity analysis, by allowing the application of various transaction, frequency, and duration values to process activities to evaluate the impact on full time equivalent (FTE) staffing requirements. Each work process was analyzed using the model. To ensure credibility, the model was benchmarked to processes of current generation nuclear power plants of similar size and design. This benchmarking used known current generation plant process values as input and adjusted activity distribution and durations to force the model to produce the known current generation process staffing values. The process staffing values from the benchmarking effort were used as the baseline for System 80+ staffing analyses and are referred to as the "Current Reference" staffing estimate.

The results obtained for the current reference plant were then analyzed to determine the benefits gained from System 80+ design improvements which are aimed at lowering plant operations and maintenance costs. Based on these design improvements, an estimate of the beneficial impact was determined and applied to the current reference plant staffing requirements to produce the System 80+ FTE staff. This is expected to be the minimum realistic FTE for a single, mature, self-sufficient System 80+ standard plant. The estimate is based solely on the technical requirements of the System 80+ design and does not include FTE for other purposes such as regulatory mandated minimum staffing. (Table 6)

Based on various System 80+ design improvements (such as optimized equipment arrangement), improvement factors were developed and applied to the current reference estimate to produce the System 80+ FTE estimate.

The results of the staffing study show that a single, mature System 80+ standard plant can be operated and maintained by a plant staff of 415 (FTE), which equates to 0.29 FTE/MWe. This represents a 30% reduction in plant staff from current plants of similar design and size. The single mature estimate also does not include FTE adjustments resulting from resource sharing with other units within a multiple unit site. A multiple unit site is expected to require less staff to operate and maintain the plant.

Table 6 Comparative Staffing Level Requirements for Large Pressurized Water Reactors

Work Process	*Current Reference*	*System 80+*
Operations	60	25
Work Control	176	150
Administrative	47	21
Configuration Change	67	53
Equipment Reliability	37	31
Material And Services	38	32
Security	85	58
Training	60	37
Waste Services	10	8
Total Full Time Equivalent (FTE) Staff	*580*	*415*
Plant Electrical Rating, MWe	*1300*	*1400*
FTE Staff Per Rated MWe	*0.44*	*0.29*

5.0 CONCLUSIONS

The detailed System 80+ refueling outage plan described in this report shows that a refueling and maintenance outage can be safely performed in 18 days, reducing overall maintenance costs and increasing availability factors for a System 80+ Standard Plant. The System 80+ refueling outage plan supports the Electric Power Research Institute (EPRI) Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD) goal to achieve an overall plant availability factor of at least 87 percent. An independent evaluation of the System 80+ Standard Plant Design concluded that an availability of over 89 percent can be achieved.

Detailed analyses were performed to determine the optimum System 80+ plant staffing level and show that operating and maintenance costs can be reduced significantly. A refueling outage plan has been developed which shows that refueling and maintenance tasks can be safely performed in 18 days, reducing maintenance costs and increasing availability.

6.0 REFERENCES

1. Design Control Document for the System 80+ ™ Standard Plant
2. System 80+™ Standard Plant Combustion Engineering Standard Safety Analysis Report Design Certification (CESSAR-DC).
3. Technical Paper TIS 96-103, Improved Safety of the System 80+ Standard Plant Design Through Increased Diversity and Redundancy of Safety Systems, presented at the 11th Annual KAIF/KNS Conference, Seoul, Korea, 1996.

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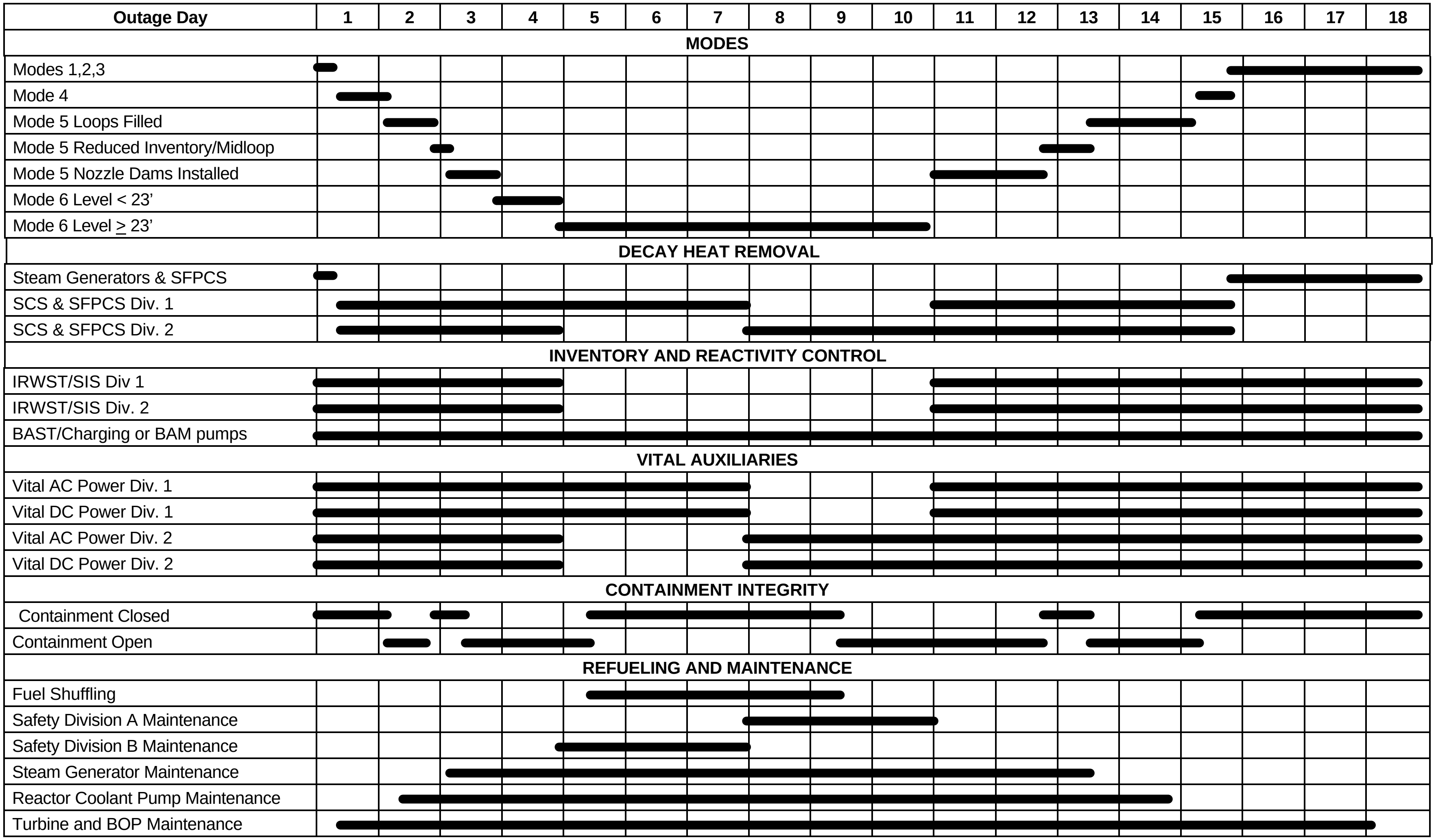

Figure 1 Integrated Refueling Outage Schedule