2001 Annual Top Industry Practice Award

Entry Form

Name or Title of Entry:

Core Redesign Using ROSA

Implementation Date:
10/1998

Name and Location of Sponsoring Plant or Utility:
Utility: TVA; Chattanooga, Tennessee
Plant: Sequoyah Nuclear Plant

Name of NSSS:
Westinghouse

Name of Software (ROSA) Supplier:
NRG, Nuclear Research and Consultancy Group, The Netherlands, www.nrg-nl.com

Process Category:
Materials, Fuel and Support Services/Handling, Storage and Disposal of Fuel

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APPLICANTS' BACKGROUND

Applicant 1

Gary Bair
BS Physics from the University of Nevada, 1968
Professional Engineer in Nuclear Engineering in Oregon and California

Worked for TVA from 1993 to present as Sequoyah Reactor Engineering supervisor. Previously worked in similar capacity at the Trojan Nuclear Plant and was lead startup testing engineer. Prior employment was with Westinghouse Electric in the startup physics group, performing initial startups on several PWRs.

Applicant 2

Jim Lemons
BS Engineering Science and Mechanics from Tennessee Technological University, 1980

Worked for TVA from 1980 to present in nuclear fuel and core engineering including fuel management, PWR safety analyses, core design. Currently, Senior Engineering Specialist directing PWR reload core design and fuel management.

Applicant 3

John Strange
BS Nuclear Engineering from the University of Tennessee, Knoxville, 1974
ME Nuclear Engineering from the University of Tennessee, Knoxville, 1977

Worked for TVA from 1978 to present in various positions in fuel procurement, fuel management, BWR and PWR transient analysis, fuel reliability, fuel rod performance, and core design. Currently, Senior Engineer in PWR Fuel Engineering responsible for reload core design and PWR fabrication and analysis contracts.

Summary Sheet for Core Redesign Using ROSA

HIGHLIGHTS

The computer code ROSA, Reload Optimization by Simulated Annealing, was procured to assist in the development of PWR reload designs. It has proven to be very useful in a variety of applications including reload core design, fuel management studies, fuel requirements projections, and core redesigns. Its value was demonstrated most recently during the redesign of the Sequoyah unit 2, cycle 11 core during the refueling outage following cycle 10.

SAFETY

The use of ROSA in the redesign process insured that the margins to safety limits for the cycle 11 design were maximized during the short time interval available to develop a revised reload core design without impacting refueling critical path time. The redesigned core achieved essentially the same margin to safety limits as the initial design.

COST SAVINGS IMPACT

Using ROSA for the core redesign enabled a revised design to be established without impacting the refueling outage length. It is estimated that using ROSA saved approximately 36 hours of outage duration.

PRODUCTIVITY AND EFFICIENCY

The use of ROSA significantly reduced the amount of time needed to develop a revised core design for cycle 11. This enabled refueling personnel to continue their activities without stopping work to await changes to the fuel assembly transfer sequence needed to implement the redesign. Productivity and efficiency were enhanced in the reload design process and in completing the physical work needed to reload the core for cycle 11.

INNOVATION

ROSA employs a graphical interface which provides the user a view of the quarter-core representation of the core and the most reactive fuel available in the spent fuel pool. Changes to the design can be made by dragging and dropping fuel assemblies using the workstation mouse. The results of the change are displayed in less than one second. The user can manually explore changes to the core design or use ROSA's automatic optimization mode. Utilizing the features available in the graphical interface, the user has complete control over the scope of changes that the code will make during pattern optimization. ROSA's speed significantly reduces the time it takes for the core designer to find an acceptable core redesign pattern.

TRANSFERABILITY

The ROSA methodology is applicable to all PWRs.

OUTSTANDING ATTRIBUTES

The speed, accuracy, and ease of use make ROSA a valuable tool for developing reload core designs.

CORE REDESIGN USING ROSA

BACKGROUND

TVA procured ROSA for use in developing reload cycle core designs for Sequoyah and Watts Bar. TVA has used cycle designs developed using ROSA for many purposes, including fuel management studies, loading pattern optimization, and requirements projections. ROSA has provided the desired accuracy, speed, and ease of use to make it a valuable tool. Using ROSA in the core design process has allowed TVA to increase margins to operating limits while saving one percent in fuel costs. ROSA allows the core designer to significantly increase the number of design options considered during the development of a reload core design. Nowhere have ROSA's capabilities proven more valuable than for core redesign after the refueling outage has already begun.

Many cycle core redesigns have been needed to support the operation of TVA's PWR units. The need for redesigns has been created by forced outages, fuel assembly failures, and fuel handling damage. One redesign resulted from fuel handling damage that occurred as the core was being reloaded. Experience has demonstrated that the potential for a redesign exists until the new core is successfully reloaded and the reactor is reassembled.

For most of these changes in cycle core design it has been possible to use traditional methods of core design without delaying core loading and plant startup. The traditional methods of core design require a significant amount of time to develop a revised design and to perform the needed safety evaluations. These methods do not permit quick evaluation of a variety of options. Rather, traditional methods rely on the experience and the skill of the designer to meet the revised design specifications, to achieve acceptable margins to safety limits, and to complete these tasks quickly.

Like other utilities, TVA has been aggressively shortening refueling outages over the past several cycles. The planned length of refueling outages at Sequoyah has been reduced from 60 days to less than 20 days. When the need to revise the reload design arises during a 20 day refueling outage, there is little time available to revise the reload design and implement the changes without impacting the refueling outage schedule.

The fall 2000 refueling outage for Sequoyah unit 2 provides an excellent example of the redesign process and the benefits of using ROSA. For this outage the plan was to move all of the fuel from the reactor to the spent fuel pool, to shuffle the fuel assembly inserts as needed, and to reload the reactor for cycle 11. All of the fuel movement and insert shuffle activities were on critical path and scheduled consecutively with no free time. Delay in any of these activities would increase the length of the outage.

About a year before the end of cycle 10 refueling outage was scheduled to begin, TVA learned that the probability for the redesign of cycle 11 was higher than normal. Coolant radio-chemistry analysis indicated that at least one fuel rod had failed. Chemistry data obtained during power reductions indicated that the failed fuel was probably in the fresh fuel loaded for cycle 10.

PREPARATION FOR THE OUTAGE

The outage plan and cycle design work were completed assuming that no failures would be found in the fuel that was scheduled to be reloaded for cycle 11. In the event that no failures were found in the reinsert fuel, then the outage plan would not be impacted. TVA does not have the capability to repair a failed fuel assembly during an outage. Consequently, TVA used ROSA to investigate the impact of discharging postulated failed fuel on the cycle 11 design. The evaluation of every single fuel assembly failure possibility would have required the evaluation of 29 different redesigns assuming that the failed assembly and its three symmetric neighbors were discharged. The evaluation of two postulated failures from nonsymmetric core locations would have required the evaluation of 812 different redesigns.

TVA elected to reduce the scope of the investigation by grouping the burned fuel that was planned for use in cycle 11. The planned reinsert fuel was segregated into 8 groups with similar enrichment and burnup. To minimize the impact of the redesigns on the planned cycle 11 design, the scope of each redesign was limited. No changes were allowed in the location and burnable absorber loading of the fresh fuel. The burned fuel was shuffled as needed to minimize the local fuel rod power and maximize the energy capability of the redesigned core.

The results revealed that for the worst case of the 8 fuel assembly groups, the increase in the maximum fuel rod power could be limited to 0.5% and the reduction in full power capability could be limited to 7 full power days. These results represent the optimum results that could be achieved while not changing the fresh fuel loading for cycle 11. However, TVA did not anticipate that a redesign of this scope would be used for the actual redesign.

The cycle designs developed for the investigation allowed more changes in the placement of burned fuel than would be desirable given the goal of minimizing the impact on the outage length. If an actual redesign were to be performed for cycle 11, the goal would be to minimize the number of changes made to the planned core loading while achieving acceptable results. This goal minimizes the amount of time needed to prepare a new core loading plan and to revise the fuel assembly transfer sequence.

The investigation showed the minimum impact on peaking and cycle energy that TVA could expect to achieve in a redesign. The results provided a basis for assessing how much additional benefit might be achieved by allowing more extensive changes to the cycle 11 design.

LOAD AT RISK

For the end of cycle 10 outage, the amount of time planned to move fuel to the spent fuel pool, to shuffle the inserts as needed, and to load the reactor for cycle 11 was less than the amount of time needed to complete the safety analysis checks for a core redesign. To minimize the impact of a core redesign on the outage duration, it would be necessary to begin core load before all of the safety analysis checks were completed.

TVA uses the 50.59 process for reviewing and approving the core changes needed to refuel the plant. In the event of a core redesign, the 50.59 process would be used to control changes in the plant configuration to insure that the reload core and plant configuration remained consistent with the safety analysis checks that had been completed.

CYCLE 11 REDESIGN

During core off load two failed fuel assemblies were found. One failed assembly was a thrice burned fuel assembly which was not planned for use in cycle 11. The other failed assembly was a once burned fuel assembly. The redesign effort began as soon as the failed once burned fuel assembly was found. Since the failed once burned fuel assembly was planned for use at a control rod location, changes to the insert shuffle were needed to reposition control rods and thimble plugs.

ROSA was used to develop a candidate cycle 11 loading plan that limited the increase in the maximum fuel rod power to 1.5% and resulted in the loss of 4 days of full power capability. The change in the core loading plan affected the fuel to be loaded at 24 locations in the core. The needed changes to the insert shuffle were implemented by adding eight additional steps at the end of the previously planned insert shuffle which was already in progress. Figure 1 shows a quarter core representation of the changes to the cycle 11 design.

The candidate loading plan was provided to Framatome ANP for their review. The first calculation performed by Framatome ANP was the base cycle depletion. Their results agreed well with the ROSA results. This agreement provided confidence that the objective of redesigning cycle 11 to minimize the impact on the previously analyzed core power distribution and behavior had been achieved. With confirmation of the refueling boron concentration by Framatome ANP and completion of a 50.59 review for entering the refueling mode, the start of core reload for cycle 11 was enabled.

As expected, the redesigned core met all safety analysis checks. With planning and the use of ROSA, the cycle 11 redesign was completed and implemented without delaying the restart of the unit. TVA estimated that approximately 36 hours of outage time was saved.

One contributor to achieving these benefits is ROSA's graphical user interface. Figure 2 shows an example ROSA graphical user interface screen. The first case for this ROSA run was the initial design for Sequoyah unit 2 cycle 11. Using mouse commands the design was changed from the initial cycle 11 design to the final cycle design. The screen only shows the results for the final loading pattern, with the exception of the plot in the upper right hand corner of the screen. This plot shows the ROSA results for the maximum fuel rod power for the initial loading pattern, for each intermediate configuration, and for the final design. The plot just below shows the maximum fuel rod power as a function of cycle burnup for the final cycle design.

Figure 1. Quarter Core Fuel Assembly Shuffle for Cycle 11 Redesign

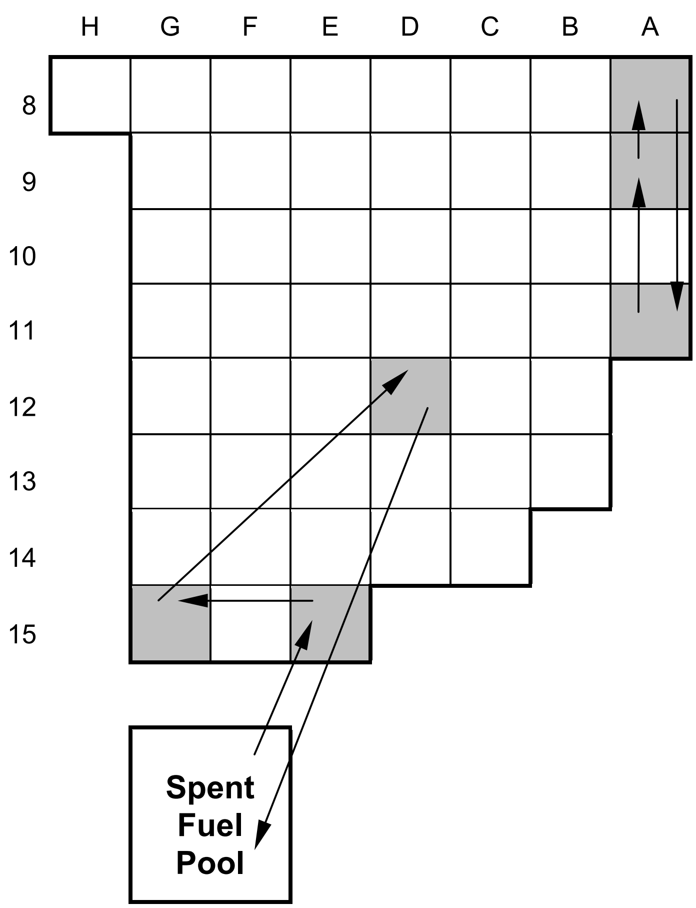

Figure 2. Sample ROSA Graphical User Interface Screen