Delivering the Nuclear Promise
Top Innovative Practice

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High Worth SCRAM Rods with TRACG-AOO Methods
2021 Top Innovative Practice Winner

Southern Nuclear Co. in collaboration with GE Hitachi Nuclear Energy deployed a first-of-a-kind application of the GEH TRACG-AOO High Worth SCRAM Rods (HWSR) flexibility option at the Edwin I. Hatch Nuclear Power Plant. This option leverages the existing NRC-approved GEH TRACG-AOO methodology for plant operating limit development with credit for the mitigating impacts of partially inserted control rods (i.e., the HWSRs). The successful implementation of the HWSR flexibility option at Hatch enabled enhanced reactor safety, provided operational flexibility and provided for reduced fuel costs by reducing the number of fresh assemblies installed in recurring reload batches.

Innovation

Southern Nuclear's application of the TRACG-AOO High Worth SCRAM Rod methodology at Hatch represents an innovative implementation of a licensed methodology to overcome the challenge of obtaining decreased fuel cost without sacrificing operating limit (OLMCPR) margin and plant operating flexibility. Design, licensing, and operation of a reactor core implementing this methodology had not been performed for any other reactor in the United States. The approach allows for the seamless realization of increased thermal limit margins and reduced fuel costs without requiring any hardware and software changes at the plant.

Background

Safety analyses for nuclear units across the fleet commonly utilize broad, conservative approximations which simplify analyses, but the resultant conservatisms in associated thermal operating limits generally prevent further reductions in reload batch size. This excess of conservatism is particularly significant regarding assumptions in the behavior of control rods in a BWR core, as most of cycle operation often occurs with rods inserted into the core in positions where they will have an almost immediate impact to mitigate the effects of a reactor scram. Until now, no attempts to control and credit the mitigating impacts of partially inserted control rods have been attempted in BWR licensing analyses. The challenge of relaxing historic conservative assumptions in the AOO methodology and practically incorporating the described modeling improvements into the reload licensing presented too high of a technical and programmatic burden before the Hatch application. This challenge is further augmented with the need to ensure that practical implementation of the associated controls on operation is not too great for utilities to implement. Other more typical approaches to the challenge of regaining needed thermal limit margin and/or reducing fuel costs generally have more extensive impacts on plant operation or economics. Typical approaches include changes/upgrades to the plant configuration and/or safety systems, reductions in power level, and/or increases in batch fraction (resulting in the purchase of more new fuel bundles and increasing fuel cost). The TRACG-AOO HWSR approach implemented by Southern Nuclear avoids the need for any of these approaches, utilizing the existing plant equipment (i.e., control rods) in configurations that were already licensed and, in some cases, typical (e.g., inserted at shallow notch positions).

Safety

The ability to implement the TRACG-AOO HWSR operating flexibility option at Hatch enhances safety by incentivizing operation in a core configuration designed to yield a more rapid and effective safety system response during a reactor scram and by providing additional thermal limit margins. These benefits are achieved via operational strategy changes (i.e., operation with shallow rods in the core) and advanced detailed AOO analyses leveraging the existing approved TRACG-AOO methodology.

The operational benefits (i.e., improved OLMCPR margins) encourage operation in a configuration which enhances the ability of the reactor protection system to mitigate a transient, thereby improving reactor safety. If a reactor scram became necessary, controlling the rods inserted to the HWSR locations increases the effectiveness of the scram and mitigates the overall impact of the event on the reactor core. Although a certain degree of the expected improvement in transient behavior is translated directly into operating limit margin, the inherent conservatism involved in all licensing analyses ensures that the actual HWSR scram effectiveness will be greater than what is credited. This effectively results in an overall less severe transient response and safer reactor operation during operation with HWSRs. Because of this, the use of HWSRs is somewhat analogous to the use of the BWR EOC Recirculation Pump Trip system, which functions to reduce the severity of transients following reactor scram. The use of HWSRs accomplishes the same results of installed safety systems through mitigation of a transient response severity but is accomplished simply by use of the existing reactor control rods without plant modification or a license submittal.

Also, the improved OLMCPR margins associated with operation in this configuration allows flexibility to manage operational challenges without unnecessary cycling of the plant or reduction in power level. Southern Nuclear's first-of-a-kind application of high worth scram rods provide significant thermal limit margin to operation during the final 1/3 of the operating cycle and during coast down, which corresponds to the point in cycle operation which generally has the lowest MCPR margins. The flexibility to regain operating margin improves the plant's ability to respond to unforeseen transients and perform maneuvers without requiring credit of plant safety systems such as the EOC recirculation trip logic.

Cost Savings

HWSR provides a flexibility option for operating limit improvement. Improvement in thermal limit margins allows a reduction in reload batch size and provides increased flexibility to deal with unplanned operational events without the need for power reduction and/or emergent unplanned reactor shutdown. This results in improved cycle capacity factors and reduced cycling of plant equipment (i.e., has the potential to reduce the magnitude of required down powers during sequence exchanges). In some circumstances, it may allow margin to ensure that needed maintenance can be more efficiently performed in fewer outages, rather than multiple mid-cycle outages. The reload design, operating strategy, and reload licensing require the plant to operate with a group of control rods pre-defined as High Worth SCRAM Rods. By eliminating excessive conservatism with the current methodology, this first- of-a-kind application has realized Operating Limit MCPR (OLMCPR) reductions by 0.04 to 0.05. This, in turn, will realize up to a four-bundle reduction in the fresh reload batch recurring for each of the subsequent Hatch reloads which leverage High Worth SCRAM Rods.

Productivity/Efficiency

The reduction in OLMCPR provides substantial operational flexibility to plant operators and reactor engineering staff to respond to equipment challenges and maneuver the plant with an additional margin, enabling increased capacity factors. The implementation requires no Technical Specification or Technical Specification

Bases revisions following the adoption of the TRACG-AOO methodology; however, it was necessary to update the COLR and numerous site procedures.

While most applications to reduce OLMCPRs of this scale require submission to the NRC for review and approval, the HWSR methodology was already incorporated into the approved TRACG-AOO methodology which allowed for immediate implementation. Before this application, utilities and the GEH team had not been able to develop an implementation approach that would successfully meet plant staff needs. Southern Nuclear's BWR Fuel Engineering team performs full scope in-house reload design, reload safety analysis, and licensing evaluations leveraging GEH methodologies. Having a utility capable of performing TRACG-AOO analysis in-house allowed for a highly efficient approach to consolidating input from all involved stakeholders (e.g., site Operations, site Reactor Engineering, GEH methodology owners, etc.) throughout the implementation process.

Transferability

The TRACG-AOO High Worth SCRAM Rods methodology and implementation framework are transferable to other utilities. Any plant that wishes to reduce OLMCPR could leverage the methodology to decrease their OLMCPR and realize increased operational flexibility and fuel cycle cost savings.

For BWRs licensed under the GEH TRACG-AOO methodology, the new HWSR process is directly transferable across the industry. Southern Nuclear BWR Fuel Engineering team has worked closely with GEH subject matter experts and established an outline/template for HWSR implementation. During the development of supporting analyses, Southern Nuclear contracted out a small portion of the highly generic statistical-based portion of the reload analyses to GEH. Southern Nuclear provided funding and oversight for these products, and their preparation by GEH allowed these generic analysis results to be established in GEH's QA system as supporting analyses for future implementation of HWSRs across the GEH BWR fleet for other GEH customers. GNF and GEH will now be able to leverage the experience they have gained to directly implement this process for other customers that request it. Also, Southern Nuclear's plant-related support products (e.g., COLR, operating procedures, etc.) are available for benchmarking by others in the industry interested in implementing this practice.

Team Members

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Additional Information

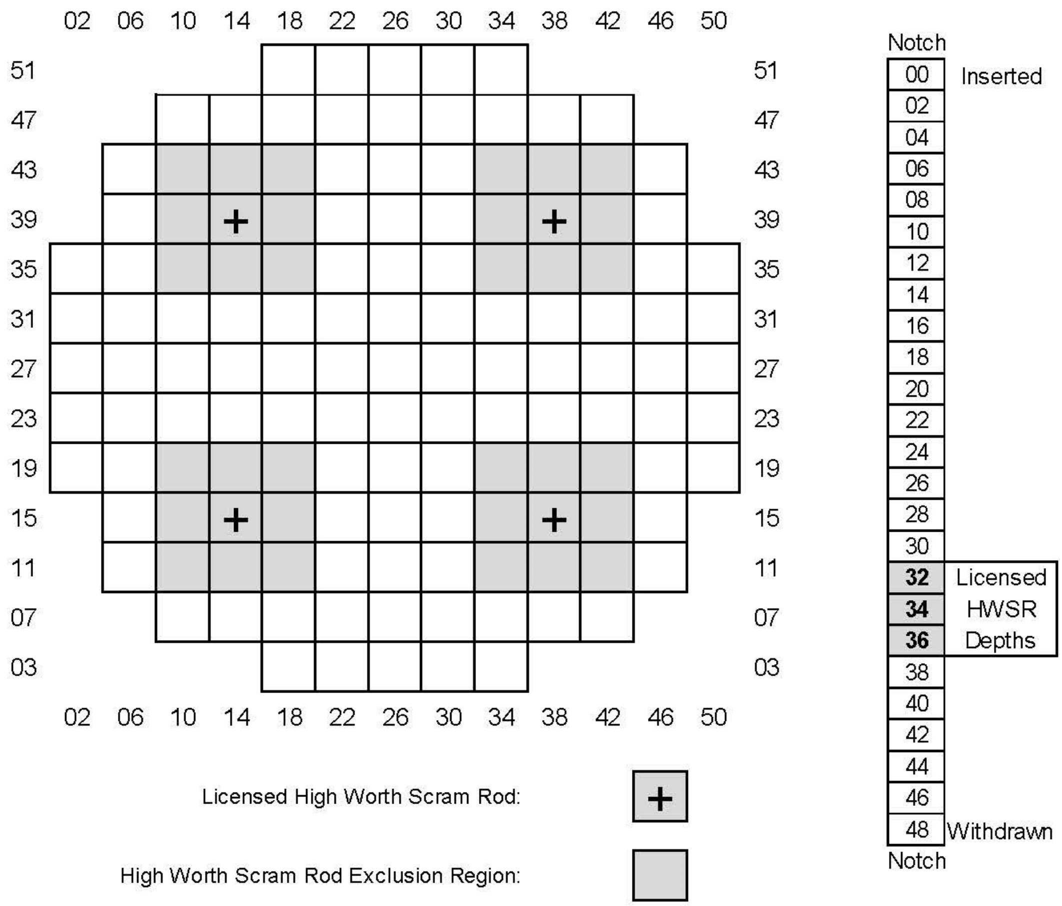
Graphic #1: Equipment Requirements

TABLE 1-2

Equipment Requirements

Equipment	Requirement
Recirculation Flow Control System	The maximum achievable core flow on the highest licensed rod line must be limited to less than 107% of rated core flow
Turbine Power/Load Unbalance Trip Logic	When operating at greater than 55% core thermal power, the turbine Power/Load Unbalance (PLU) trip logic must be functional
Feedwater Heaters	For any 4^{th} stage feedwater heater configuration off-normal, High Pressure Feedwater Heaters Out of Service limits must be applied (unless the standard LFWH analysis is demonstrated to remain applicable by BWR Fuel Engineering)
APRM System	The Oscillation Power Range Monitor (OPRM) Period Based Detection Algorithm (PBDA) amplitude trip setpoint must be set equal to 1.15
High Worth Scram Rod (HWSR)	An individual High Worth Scram Rod must satisfy the following conditions to be valid for thermal operating limit improvements: • Correspond to a licensed HWSR pattern, as defined in Figure 3-5. • Control rod is inserted to a licensed HWSR notch location, as defined in Figure 3-5. • All diagonal-adjacent and face-adjacent control rods are fully withdrawn as defined by the Figure 3-5 exclusion regions. • Control rod scram time is not "slow," in accordance with Technical Specification Table 3.1.4-1.

Graphic 2: High Worth Scram Rod Set – A1 Configuration



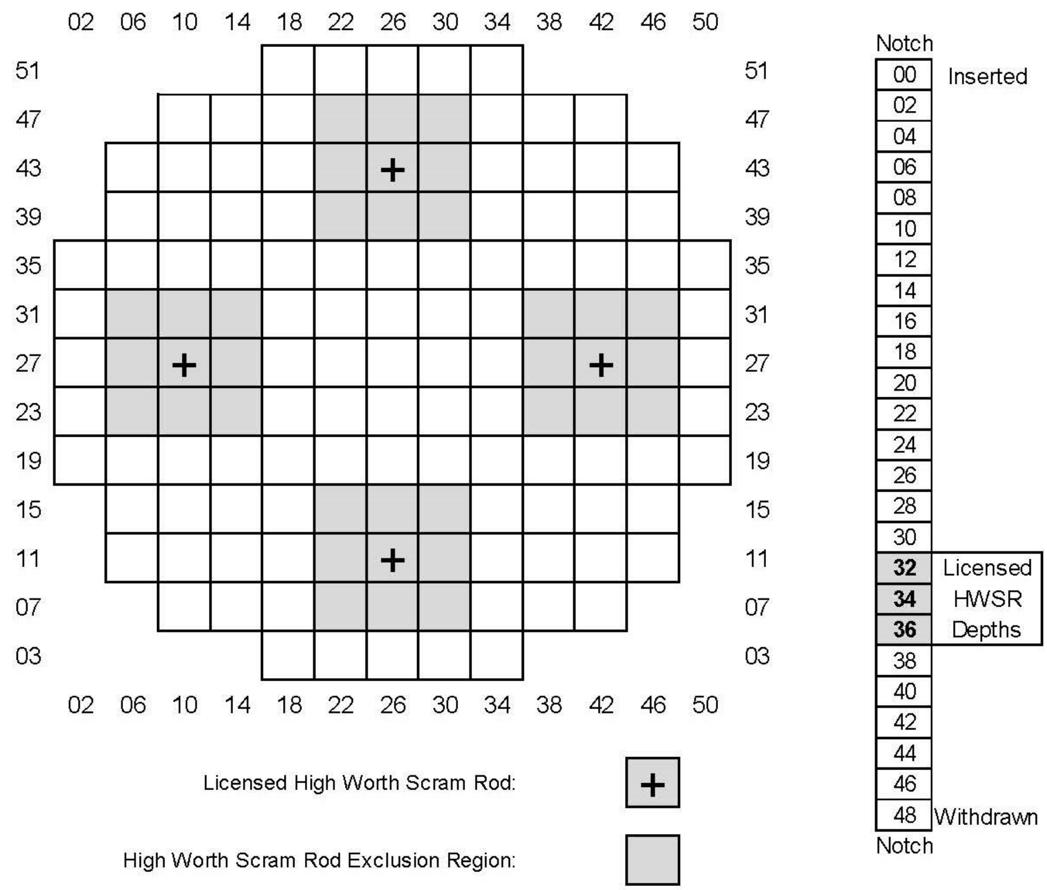
Licensed HWSR Coordinates (IX-JY)
14-15
14-39
38-15
38-39

Maximum High Worth Scram Rod Depth (Notch):	32
Minimum High Worth Scram Rod Depth (Notch):	36

FIGURE 3-5A

High Worth Scram Rod Set – A1 Configuration

Graphic 3: High Worth Scram Rod Set – A2 Configuration



Licensed HWSR Coordinates (IX-JY)
10-27
26-11
26-43
42-27

Maximum High Worth Scram Rod Depth (Notch):	32
Minimum High Worth Scram Rod Depth (Notch):	36

FIGURE 3-5B

High Worth Scram Rod Set – A2 Configuration