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Operator Workload Evaluation of Reactor Start-up Operation in the Nuclear Power Plant

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1. Introduction

- Operation automation
 - One of the powerful methods to prevent human error in the nuclear power plant
 - Becoming visible due to the development of artificial intelligence (AI) technology and Big-data analytics
 - Improved reliability of AI and Big-data is the driving power to force human operator to stand at the out-of-loop
- Start-up Operation is a better candidate for Operation Automation
 - Normal operations in the nuclear power plant are usually highly-automated already
 - The start-up operation takes a long time, requires frequent communication and comprehensive decision-makings so many unexpected reactor trips caused by human operator have been occurred
- Partial Automation
 - As radical automation, automation of every operator task, is infeasible now
 - Partial automation (automation of some parts of operator tasks) is being tried in many researches
- ◆ In order to select tasks to be automated from the whole start-up operation
 - It is critical to figure out the level of operator workload for the startup operational tasks
 - In this study, operator workload for each task of the start-up procedure was evaluated

2. Method and Results

- Target Operation and Procedures
 - Procedure #3001 : from Cold Shutdown to Hot Standby
 - Procedure #3002 : from Hot Standby to 5% Power (before a 25% Power level)
- Subjective Workload Rating
 - Five (5) experienced & retired operators took part in the rating
 - Range of rating score: 1 (lowest workload) ~ 9 (highest workload)

• Scoring Results



Table I: Statistics of Evaluation Scores for Procedure#3001

	mean	Standard deviation
SME 1	5.961967720	1.711134053
SME 2	5.968369615	1.801023611
SME 3	5.440382842	1.622739450

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SME4	5.227060574	1.436063331
SME5	5.735083843	1.410175922



Raw Data (Procedure #3002)



Table II: Statistics of Evaluation Scores for Procedure#3002

	mean	Standard deviation
SME 1	6.406261992	1.777866540
SME 2	5.611760858	1.620778428
SME 3	4.718688587	1.466425977
SME4	4.961215042	1.168977573
SME5	5.448435229	1.336009883





High level of Workload

From the evaluation scores, operators are expected to take the highest level (7.6) of workload from several tasks as followings:

- Procedure#3001 Section 16 (Checking before RCP startup)
- Procedure#3001 Section 31 (Maintaining PZR level at 40%)
- Procedure#3001 Section 59 (Leakage test of RCS pressure isolation valve)
- Procedure#3001 Section 67 (Pre-heating turbine)
- Procedure#3002 Section 6 (Pre-heating turbine)

3. Conclusions

Investigation of workload level for each procedure task is essential to make a plan for automation of startup operation. Evaluation process by experienced operators was carried out for start-up operation from cold shutdown to the 5% power operation. As the results, tasks that give operators high level of workload were identified.

Application

It is beneficial to automate the high level workload tasks for human error reduction and safety This study provides essential information for planning task automation strategy

Further Works

Detail Analysis: A plan to look into lower level tasks of each start-up task is established