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An Approach to Establish Design Requirements for Human-System Interface (HSI) of Automatic Systems in Nuclear Power Plants

Nuraslinda Anuar and Kim Jonghyun
KEPCO International Nuclear Graduate School (KINGS)
1456-1 Shinam-Ri, Seosaeng-myeon, Ulju-gun, South Korea (689-882)
**Corresponding author: lynnanuar@gmail.com*

1. Introduction

The existing human factors engineering (HFE) guidance and guidelines [5, 6] do not deal with the HSI design for automatic system sufficiently as they do not explicitly include when and which LOA each guidance is applicable to. This paper aims to demonstrate an approach to establish the design requirements for automatic systems in nuclear power plant (NPP) by using a powerful tool called Itemized Sequence Diagram (ISD).

The process starts with function allocation by defining a set of levels of automation (LOAs). Then, task allocation is done using the ISD and finally the design requirements are established by examining the interaction points between human operator and automation, which are all located on the interface as modeled in the ISD. The strengths of this approach are discussed and a suggestion to integrate with that of the methodology employed to produce the existing guidelines or guidance is included in this paper.

2. Issues of Automation

The inclusion of automation in the operation of a NPP has caused some problems because automatic system is mostly inadequately designed to support operator in critical conditions [1]. Firstly, the problem in understanding automation behavior [1] results in the out-of-the-loop (OOTL) performance problem [2] due to the inefficient interaction between human operator and automation. Secondly, the tendency of system designer to design for multiple modes has led to the increased possibility of mode errors for operators.

Thirdly, automation requires for operators to have new roles, namely supervising and coordinating. Finally, sometimes the system is designed in such a way that hinders human operator rights to make the final call, hence the final ultimate authority issue.

3. Function Allocation and Task Allocation: Modeling with ISD

A set of LOAs is defined to identify functions and high level tasks that need to be assigned to each of the control agents, namely human operator and automation. This LOA defining process is done through the four chronological process stages in NPP operation, which are (1) information acquisition, (2) plant condition diagnosis, (3) response selection and (4) response implementation.

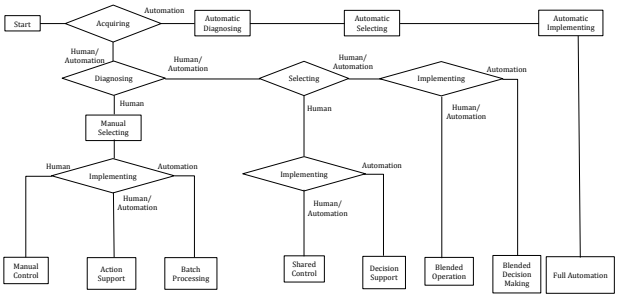

Fig. 1. Decision framework for defining LOAs

Fig. 1 shows the decision framework for LOA defining process that was modified based on [3]. A total of eight LOAs were defined and the control agents responsible for each of the operational process stages are summarized in Table I below.

Table I: The LOAs defined in this paper with human (H), human/automation (H/A) and automation (A) as control agents

Level of Automation (LOA)	Process Stages			
	1	2	3	4
Manual Control (MC)	H/A	H	H	H
Action Support (AS)	H/A	H	H	H/A
Batch Processing (BP)	H/A	H	H	A
Blended Operation (BO)	H/A	H/A	H/A	H/A
Blended Decision Making (BDM)	H/A	H/A	H/A	A
Shared Control (SC)	H/A	H/A	H	H/A
Decision Support (DS)	H/A	H/A	H	A
Full Automation (FA)	A	A	A	A

Next, task allocation can then be carried out by drawing the ISD for each of the LOAs. An ISD is a more detailed version of the existing sequence diagram of the Unified Modeling Languages created by Object Management Group [4]. The ISD for Blended Operation LOA is used for analysis because of the largest number of interactions between the control agents that it has. Design requirements are then established with the motivation of ensuring that the interaction between human operator and automation is efficient as possible.

4. Results: Design Requirements for HSI of Automation in NPP

A set of design requirements is constructed based on the ISD and the existing pitfalls of automation. Table II

shows the produced design requirements and the LOAs that each requirement is applicable to. Fig. 2 summarizes the origin of the establishment of each design requirements from the ISD.

Table II: The design requirements produced and the applicable LOAs for each requirement

Requirement	Applicable LOAs
The HSI for automation should be designed to provide the necessary raw information to the operator	All
The HSI should display the processed raw information to the operator	All
The HSI should provide the automation diagnosis results to the operator	All except for MC, AS and BP
The HSI should display the suggested response	BO, BDM and FA
The HSI should show the technical basis of each of automation's activities to the operator whenever requested	All
The HSI should allow for human operator to input the request for additional information to automation	All
The HSI should receive response selection or change in response selection by the operator and send the selection to the system	All except for FA
The HSI should send automation's request for human operator approval to implement some tasks, receive the approval and send the approval to the system	AS, BO and SC
The HSI should display the progress and status of implementation	All
The HSI should display the stability parameters for automation failure detection and the possible need for manual control notification	All
The HSI should provide the means for take-over from automatic control to manual control	All except for MC
The HSI should present the current control mode and the transition between automatic control and manual control to human operator	All except for MC

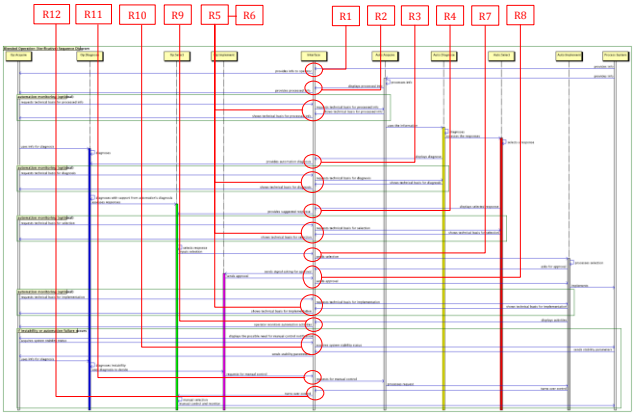

Fig. 2. The ISD for Blended Operation LOA and the corresponding requirements.

5. Discussion

Table III summarizes which automation issues each design requirement addresses. The methodology employed in producing the existing design guidance uses operating experiences and an evaluation approach through a set of pre-determined scenarios [5]. In this paper, the design requirements are established from the utilization of the ISD, which is a very concrete and direct approach that can be applied to identify the points of interaction between control agents.

Table III: The design requirements produced and the applicable LOAs for each requirement

Automation Issues	Requirements Encompassing the Issues
Out-of-the-loop performance	All except for R7, R8 and R11
Mode error	R7, R9, R11 and R12
Role change to supervisor	R6, R9, R10 and R12
Authority	R3, R4, R7, R8, R9 and R11

The process of drawing the ISD is done with the goals of improving the interaction between the control agents hence an almost "ideal" interaction is described through the flow of arrows. This paper presents the usefulness of the ISD, which is not being used to produce the existing guidance.

Another strength of the approach proposed in this paper is that it can be seen clearly from the ISD which requirement is applicable to which LOA, and which stage of process stages the requirement is applicable to.

6. Conclusions

Some issues of automation have been addressed earlier in this paper and 12 design requirements that address human-system interaction were suggested by using the ISD as a tool to identify the interaction points between human operator and automation.

The integration of the proposed approach in this paper with that of existing guidance could result in the new issue identification that would call for the establishment of new guidance. For example, Requirement 11 states that the HSI should provide the means for take-over from automatic to manual control was not mentioned in the existing guidance [5, 6].

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