Automation-aided Task Loads Index based on the Automation Rate Reflecting the Effects on Human Operators in NPPs

Seung Min Lee [a*], Jong Hyun Kim [b], Poong Hyun Seong [a]
[a]*Department of Nuclear and Quantum Engineering, KAIST, 373-1, Guseong-Dong, Yuseong-Gu, Daejeon, South Korea, 305-701*
b KEPCO International Nuclear Graduate School, 1456-1, Shinam-ri, Seosaeng-myeon, Ulju-gun, Ulsan, Republic of Korea
[*]*Corresponding author: jewellee@kaist.ac.kr*

1. Introduction

Since automation was introduced in various industrial fields, the concept of the automation rate has been used to indicate the inclusion proportion of automation among all work processes or facilities. Expressions of the inclusion proportion of automation are predictable, as is the ability to express the degree of the enhancement of human performance. However, many researchers have found that a high automation rate does not guarantee high performance. Therefore, to reflect the effects of automation on human performance, a new estimation method of the automation rate that considers the effects of automation on human operators in nuclear power plants (NPPs) was suggested [1]. These suggested measures express how much automation support human operators but it cannot express the change of human operators` workload, whether the human operators` workload is increased or decreased. Before considering automation rates, whether the adopted automation is good or bad might be estimated in advance. In this study, to estimate the appropriateness of automation according to the change of the human operators` task loads, automation-aided task loads index is suggested based on the concept of the suggested automation rate.

2. Estimation Method of the Automation Rate

2.1 System Automation Rate

The concept of the automation rate has been recognized since automation was introduced in various industrial fields. In manufacturing industries, terms such as the process automation rate or the facility automation rate have been broadly mentioned. The portions of tasks substituted by automation and let us know how much the automation can relive human operators` tasks. However, it cannot define how much a human is supported by automation. To create an automation rate with a measure that accounts for the effectiveness of human operators, changed or newly generated human operators` tasks due to the acceptance of automation system should be considered.

Figure 1 shows that, when automated, some tasks are replaced and others are assigned to human operators. In addition, monitoring tasks that check whether the automation properly performs its tasks are newly generated.

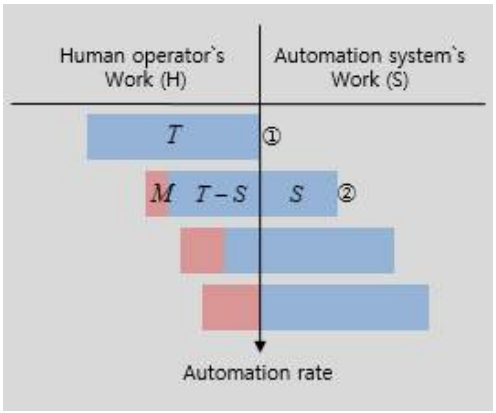

Fig. 1. Changes of the work responsibility between operators and automation systems.

Thus, a system automation rate that considers the monitoring tasks newly generated due to acceptance of system automation is required and it is defined as follows:

$$\frac{S}{T+M}\times 100\,[\%]$$

where,
T: total number of original tasks
S: the number of automation system`s tasks
M: the number of newly generated monitoring tasks

2.2 Cognitive Automation Rate

When system automation conducts the number of tasks S, the remaining tasks, including the newly generated tasks, i.e., T-S+M, should be achieved by human operators. Most of the tasks in NPPs are described in procedures. Thus, the number of tasks that human operators should cover can be found by analyzing the procedures. As the main control room (MCR) is digitalized and because computer systems are widely applicable to NPPs, numerous computer-based human operator support systems have been developed.

Among them, it is necessary to concentrate on the CPS, which will replace the existing paper-based procedures. The CPS has the original functions of the procedures, that is, to command what human operators should do. It can also contain additional functions that summarize and reduce the information to a succinct form or that monitor and diagnose the status, for instance. CPSs including these functions can allow human operators to conduct tasks which require human cognitive functions [2].

If cognitive automation such as CPSs is accepted, the number of human operators` tasks does not change but the human cognitive task loads to when carrying out the tasks is reduced. Therefore, a cognitive automation rate considering how much the automation can reduce the required human cognitive task loads can be defined.

$$\left[1-\frac{\sum_{i=1}^{H} f_{n(x_i)}(x_i)}{\sum_{i=1}^{H} f_1(x_i)}\right]\times 100[\%]$$

where,
H: total number of human operator`s tasks (H=T-S+M)
x_i :i^{th} task
$n(x_i)$: automation level of ith task
$f_{n(xi)}(xi)$ required cognitive load for doing xi task which is n-level automated

To quantify the human cognitive task load, Conant`s model, which is an information-theory-based information-flow quantification method, was used [1,3].

3. Automation-aided Task Loads Index

It is commonly believed that automated systems can reduce the human error and enhance the system performance. However, inappropriately accepted automation system can increase the workloads and decrease the efficiency by imprudently generated new monitoring works. Thus, to estimate the change of human operators` task load affected by accepting automation, the automation-aided task load index is suggested.

$$\frac{H}{T}\frac{\sum_{i=1}^{H} f_{n(x_i)}(x_i)}{\sum_{i=1}^{H} f_1(x_i)}$$

where,
H: total number of human operator`s tasks
T: total number of original tasks
x_i :i^{th} task
$n(x_i)$: automation level of ith task
$f_{n(xi)}(xi)$ required cognitive load for doing xi task which is n-level automated

The automation-aided task load index can be used to calculate the change of task loads and estimate how much an amount of human operators` task load is changed. The result has a range from 0 to 1or higher. If the system is fully automated, then there is no required human cognitive task load and the automation-aided task load index is calculated as 0. If the system is conducted without automation (n=1), then the suggested index is calculated as H/T=1. Here, the suggested measure can have the value over 1 in case that the total number of human operator`s tasks (or newly generated monitoring tasks) are inadequately increased because of inappropriate introducing automation.

From the suggested measure, simple estimation of newly accepted automation can be conducted by comparing the automation-aided task load index.

4. Conclusions

To insure plant safety and efficiency on behalf of human operators, various automation systems have been installed in NPPs, and many works which were previously conducted by human operators can now be supported by computer-based operator aids. According to the characteristics of the automation types, the estimation method of the system automation and the cognitive automation rate were suggested. The proposed estimation method concentrates on the effects of introducing automation, so it directly express how much the automated system support human operators. Based on the suggested automation rates, the way to estimate how much the automated system can affect the human operators` cognitive task load is suggested in this study.

When there is no automation, the calculated index is 1, and it means there is no change of human operators` task load. The calculated index is 0 when the system is fully automated. The suggested index has a value higher than 1, and it means new monitoring works are inappropriately generated because of inadequate acceptance of automation. The suggested automation-aided task loads index can be a simple way to estimate whether the automation is introduced well or not before considering calculation of automation rate or optimization of automation rate.

REFERENCES

[1] Lee, S.M., Kim, J. H., Seong, P. H., Estimation Method of Cognitive Automation Rates Reflecting the Effects of Automation on Human Operators in Nuclear Power Plants, Nuclear Engineering and Design (submitted)
[2] Fink, R. T., Killian, C. D., Hanes, L. F., Naser, J. A., 2010. Guidelines for Design and Implementation of Computerized Procedure Systems: An Update. International Conference on Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies, Las Vegas, Nevada, 1157-1168.
[3] Kim, J. H., Lee, S. J., Seong, P. H., 2003. Investigation on Applicability of Information Theory to Prediction of Operator Performance in Diagnosis Tasks at Nuclear Power Plants. IEEE Transactions on Nuclear Science. 50, 1238-1252.