# An Evaluation of the Unexpected Trip Limits Using the Quality Control Approach

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## 1. Introduction

Korea has 20 nuclear power plants under operation, maintain a high availability. Comparing the statistics on the unexpected trip frequency in USA(1.1~1.4/RY), Canada(1.1~3.1/RY), and France(18.~3.2/RY), respectively, that of Korea is shown to be much less in a value of 0.4~1.0/RY in recent 5 years. In fact, the unexpected reactor trip tends to be recognized as a severe accident to public in Korea. Therefore the Korea Institute of Nuclear Safety(KINS) make efforts much to reduce the unexpected reactor trip frequency. But unexpected reactor trip frequency is not directly connected to severe accident, and an artificial effort to reduce trip frequency is very danger for nuclear plant. To overcome this problem, it is shown that a new approach using the concept of upper control limits(UCLs) in the quality control may be applicable to suggest the criteria of the unexpected trip frequency.

## 2. Methods and Results

A new method to evaluate the unexpected trip limits using the quality control approach is introduced in this section. The quality control(QC) approach is utilized to derive the acceptable limit of the unexpected trip frequency.

### *2.1 Statistical Analysis*

In case the statistical value goes beyond the standard of the frequency, it is considered that this plant condition is not normal.

A sigma value which is equivalent to 68% in population is used to establish the intervals for random variable of the unexpected trip frequency.

Table I: Data of Each Power Plant

| Plants | Observations | Sum | Average | Variance |
|---|---|---|---|---|
| KRN1 | 20 | 44 | 2.2 | 8.379 |
| UCN1 | 20 | 34 | 1.7 | 2.958 |
| WSN1 | 20 | 20 | 1 | 1.158 |
| YGN1 | 20 | 21 | 1.05 | 1.103 |
| UCN4 | 11 | 10 | 0.91 | 0.491 |
| YGN3 | 10 | 3 | 0.3 | 0.456 |

Table I is specific data of each power plant. As analysis result by one-factor layout, p-value is calculated by 0.040867(less than 0.1).[1,2] It is certify that each plant has the unique breakdown rate. So we need a standard of reactor trip frequency in order to do a reactor trip administration efficiently.

### *2.2 Data analysis on Recent Trips*

In this study, reactor trip data of latest 5 years is analyzed in detail. It is analyzed that causes of reactor trip consist of electricity error, measure error, machine error, and human error.

-Electricity errors : The case that problem happens actually in electrical appliances, or reactor stop occurs by malfunctions of the electrical appliances connection safety device
-Measure errors : The case that measure device established for safety of power plant causes the bug and the reactor stop occurs.
-Machine errors : The case that the problem happens by the mechanical causes and reactor trip occurs.
-Human errors : The case that reactor trip happens by the operator.

As a result of surveys, it is found that the reactor trip occurred by electricity errors are 22 times, by measure errors, 18 times, by machine errors, 8 times, by human errors, 8 times, respectively.

### *2.3 Quality Control Approach*

The effective quality control methods have become increasingly important as industries strive to design and produce more reliable products more efficiently. Attention has been focused on the “quality” of a product or service, which is considered to be a general term denoting how well it meets the particular demands imposed upon it. Many quality control methods incorporate techniques involving probability and statistics.[1]

In this study, reactor trip distribution is construed that is poisson distribution. So lambda control chart is used in estimate of upper control limit.

### *2.4 Evaluation of the Unexpected Trip Frequency*

UCL(Upper Control Limit) is drawn by refer to passing 20 years reactor trip data. Table II shows it.

Table II: Reactor Trip Data of Recent 20 Years

| Years | 90 | 91 | 92 | 93 | 94 |
|---|---|---|---|---|---|
| #/RY | 1.78 | 3.67 | 2.11 | 2.56 | 0.90 |
| Years | 95 | 96 | 97 | 98 | 99 |
| #/RY | 2.27 | 1.73 | 2.08 | 1.67 | 1.31 |
| Years | 00 | 01 | 02 | 03 | 04 |
| #/RY | 0.56 | 1.06 | 1.06 | 1.10 | 0.85 |
| Years | 05 | 06 | 07 | 08 | 09 |
| #/RY | 1.00 | 0.75 | 0.95 | 0.45 | 0.40 |

When do UCL calculation, applied 1-sigma control limit and next formula is used.

$$UCL = \lambda + \sqrt{\lambda} \quad (1)$$

1-sigma control limit is selected by AHP(Analytic Hierarchy Process), [3,4,5] and λ is postulated as 1.413 through recent trip data. So UCL is calculated as 2.609. Fig.1 shows UCL of unexpected reactor trip frequency.

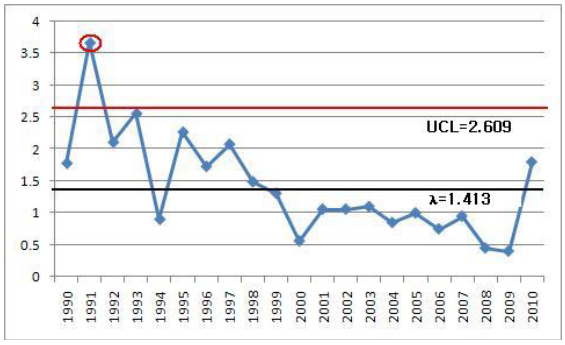


Fig. 1. UCL of Unexpected Reactor Trip Frequency

### 3. Conclusions

Unexpected reactor trip frequency is not directly connected to severe accident, and an artificial effort to reduce trip frequency is very danger for nuclear power plant. But it is generally thought that the lowest trip frequency makes the best result. Therefore, we need to establish a standard criteria of unexpected reactor trip frequency.

AHP and QC method are used in this study. In calculation doing with the data during the latest 20 years, upper control limit is calculated as 2.609. Average reactor trip frequency value of 1999 exceed UCL. However, the recent trip frequencies are satisfying standard.

The result of this study is considered to contribute to improvement of safety in nuclear power plant.

### Acknowledgements

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### REFERENCES

[1] Anthony J. Hayter, "Probability and Statistics for Engineers and Scientists", Duxbury Press, Belmont, 2006.
[2] Ang, A. H-S., W. H. Tang. "Probability Concepts in Engineering Planning and Design." Vol. I: Basic Principles. John Wiley & Sons, Inc., New York , 1976.
[3] Saaty Thomas L. "The Analytic Hierarchy Process." McGraw-Hill Inc., New York, 1980.
[4] Saaty Thomas L., "How to make a decision: The analytic hierarchy process", European Journal of Operational Research, Vol. 48, pp. 9-26, 1990.
[5] EMBREY, D.E., Humphreys, P.C., Rosa, E.A., Kirwan, B. & Rea, K., SLIM-MAUD: "An approach to assessing human error probabilities using structured expert judgement." NUREG/CR-3518, 1984.