A New Approach to the Statistical Setpoint Drift Management

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1. Introduction

The nuclear industry has widely adopted the approach suggested in ISA-RP67.04 [1] for ensuring that the setpoints for safety-related instrumentation are established and maintained within the tech spec limits [2]. The current setpoint drift analysis method corresponding to a dashed rectangle area in Figure 1, is closely related to the estimation of the maximum expected drift value, so-called 95/95 tolerance limits (TL). The 95/95 TL means that we are 95% sure that 95% of all past, present, and future drift values will be bounded by the limits. However, the current approach is inefficient when applied to the drift management, because it is no more than a guideline for determining a setpoint under uncertainty as well as it has some deficiencies such as the incompleteness of the analysis procedure (*e.g.*, the scope bounded by the sample size of 30 or above), the absence of the drift pattern/trend analysis, etc. In this paper, we propose a new statistical analysis procedure for the setpoint drift management using the as-found (AF; prior to any adjustment) and as-left (AL; required if there is a need for adjustment) data. Some illustrations and the SeDA (Setpoint Drift Analysis) program to implement the new procedure are described in the technical report [3] written by the authors.

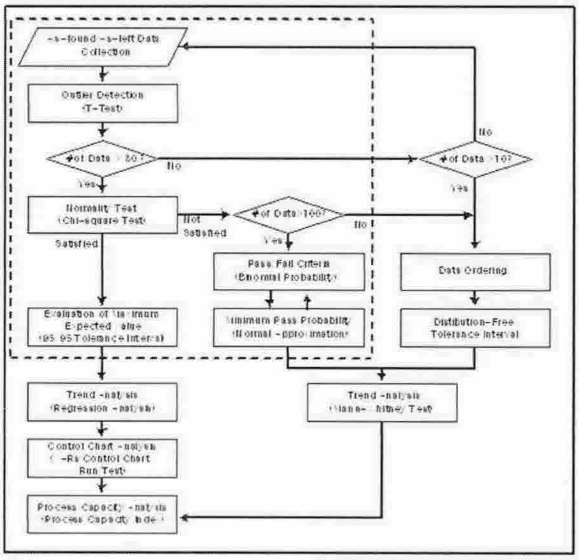

Figure 1. A new statistical drift control procedure

2. The New Methodology for the Drift Data Analysis

The procedure for the new methodology consists of six steps: 1) outlier detection, 2) normality test, 3) evaluation of the maximum expected drift value, 4) trend analysis, 5) control chart analysis, 6) process capability analysis (See Figure 1). The first three steps, based on the statistical prediction techniques for estimating the 95/95 TL, are closely similar to those of the conventional approach, except for the adoption of some graphical tools and the additional distribution-free statistical techniques. The remaining steps 4 to 6, based on the statistical process control techniques, were newly added to manage the setpoint drift of an individual I&C device.

2.1 Outlier Detection

Prior to a drift analysis, the AF/AL data should be converted to a common base, *i.e.*, percentage drift.

$$D_i = (AF_i - AL_{i-1}) / R \times 100 \quad (1)$$

where D_i stands for the percentage drift of the ith test period and R for the span of the instrumentation. The percentage drift data is used instead of the AF/AL data. An outlier is an observation that is significantly different from the rest of the sample. They usually result from a mistake or imprecision of the measurement. In the conventional approach [1], the T-test can be used for the identification of the outliers. In the new approach proposed, however, the box-plot [3] can be recommended instead of the T-test appropriate only when the drift data can be represented by a normal distribution.

2.2 Normality Test

A Chi-square goodness-of-fit test [1] is used to assure that the underlying distribution can be represented by a normal distribution. This test predicts the expected number of observations for each interval deviding the entire range of the fitted normal distribution. The precise form of the test depends on whether or not we have estimated any of the parameters of the fitted distribution from the sample data. Note that it should be applied only to groups with a large population of, say, 30 or more data points. Thus, the use of the K^2 statistics based on the normal percentage-percentage (P-P) plot [4] is suggested in the new procedure, in lieu of Chi-square test.

2.3 Evaluation of Maximum Expected Drift Value

If the normality for the percentage drift data is valid, the maximum expected drift value (D_{MAX}) can be easily determined by the following equation.

$$D_{MAX} = \left|\overline{D}\right| + K \times S, \quad (2)$$

where $\overline{D}$ is the sample mean, S is the sample standard deviation, and K is a 95/95 tolerance factor[5], *e.g.*, 3.38 for the sample size (10), 2.75 for (20), 2.55 for (30), 2.38 for (50), and so on.

If not, the arbitrary pass/fail criteria and the minimum pass probability can be used together for obtaining a 95/95 TL [1]. In nuclear industry, however, it seems likely to be impractical because of sufficiently large sample points (>100). As shown in Figure 1, such a probem has been solved in the new procedure by estimating a distribution-free TL using the ordered percentage drift data (e.g., $D_{(1)},...,D_{(i)},...,D_{(n)}$) [6]. Then, it is said that the interval of $[D_{(1)}, D_{(n)}]$ is the 100 β percent distribution-free TL at probability level γ defined by

$$\gamma = 1 - n \cdot \beta^{n-1} \cdot (1-\beta) - \beta^{n}. \quad (3)$$

2.4 Trend Analysis

For the trend analysis, a simple regression analysis can be used. From the F-test using the analysis of the variance (ANOVA), we can decide if the null hypothesis of 'no trend' is accepted or not. However, the collinearity and non-normality due to imprecision of measurement may cause some difficulties in obtaining rigorous results from a regression analysis. In these cases, a distribution-free trend analysis method (Mann-Whitney test) is considered [3]. The test statistics is defined by the following equation.

$$W = \sum_{i=1}^{n-1} \sum_{j>i}^{n} I\{D_i > D_j\} \quad (4)$$

where $I\{D_i > D_j\}$ is the index function. Thus, we can accept the hypothesis of 'no trend' with a significance level α if $\left|(W - E(W))/\sqrt{V(W)}\right| < Z_{\alpha/2}$,where Z is a quantile of the standard normal distribution. Mean and variance of W are $E(W) = n(n-1)/4$ and $V(W) = n(n-1)(2n+5)/72$, respectively. The sample size, n, should be 10 or above.

2.5 Control Chart Analysis

The control chart is used to identify the abnormal pattern of the process from its variation and predict the future behavior of the process. The point of making control charts is to look at the variation of the process. The individual data and moving range (X-Rs) control charts are appropriate for our concern [3]. Anomalies in X-Rs chart can be identified using several rules: 1) 1 data point falling outside the control limits, 2) 6 or more points in a row steadily increasing or decreasing , 3) 8 or more points in a row on one side of the centerline, or 4) 14 or more points alternating up and down.

2.6 Process Capability Analysis

The process capability analysis is adopted to measure the proportion of the in-specification process when it is in a state of statistical control [7]. It is a widely-accepted practice to express a processes capability using the two indices, C_p and C_{pk}. If the process is centered, C_p is the simplest process capability index, defined by the equation

$$(USL - LSL)/6S \quad (5)$$

where USL and LSL are the upper and lower specification limits, respectively. If not, a capability index which takes process centering into account (C_{pk}) is required. C_{pk} is the difference between the process mean and the nearer specification limit divided by 3σ, which is estimated by

$$Minimum\{(USL - \overline{D})/3S, (LSL - \overline{D})/3S\}. \quad (6)$$

If C_p or $C_{pk} \geq 1$, the process is in a state of an in-specification process. If C_p or $C_{pk} < 1$, more non-conforming processes are being made.

3. Conclusion

New methodologies for the statistical drift control analysis were proposed to manage the instrument setpoint drift using the plant specific AF/AL data in this paper. The use of the new procedure can provide useful tools for plant staff to easily realize the abnormal performance of the instrumentation in advance. In particular, statistical graphic tools can facilitate the process of the previous drift evaluation. The adoption of the non-parametric statistical methods enlarges the scope of the drift analysis from the view point of the methodology. Several statistical process control techniques will provide the plant staff with more efficiency in managing the individual I&C device.

REFERENCES

[1] ISA, Methodologies for the Determination for the Nuclear Safety-Related Instrumentation, ISA-RP67.04, Part II, 1994.

[2] US NRC, Setpoints for Safety-Related Instrumentation, RG1.105, Rev.3, 1999.

[3] S.C. Jang, Development of the Statistical analysis Methods for Managing Setpoint Drifts, KAERI/TR-2167/2002, 2004.

[4] M. Kendall, The Advanced Theory of Statistics, Vol.II, Griffin, London, 1979, pp.547-550.

[5] F.F. Gan, Goodness-of-Fit Tests Based on P-P Probability Plots, Technometrics, V.**32**, No.3, 1990.

[6] W.J. Beggs, Statistics for Nuclear Engineers and Scientists, Bettis Atomic Lab., EDB-81-038526 (WAPD-TM-1292), 1981.

[7] V.E. Kane, Process Capability Indices, J. Quality Technology, V.**18**, 1986, pp.41-52.