To judge the power circuit breaker interrupting time and the prediction of maintenance schedule with Normal distribution probability

Original Research Article

ABSTRACT

In this article, begins with the motivation for compiling, literature review, and normal distribution theory and characteristics with a shallow example to explain.**Design Method:** Making an approximately qualitative normal distribution with EXCEL software. First, the sample group plays an important role in the article, it with the cooperation of EXCEL application software and normal distribution rules, can be establish what those the relevant parameters of normal distribution.Taking the relevant parameters to drawn into a bell-shaped curve graph, then the standard score and probability of the area of the bell-shaped curve is out of converted.**Design Purpose:** As a detection tool of judgement.

In this way, anapproximately qualitative normal distribution is been formed and its mean, variation and standard deviation are been took as a detection based to evaluated what the probability of any random variable of the same type. **Design Effectiveness:** To judge of equipment inspection data and work schedule prediction. However, anapproximately qualitative normal distribution is been constructed with actual data to calculate out of being relevant parameters, with those ones to judge the interruption time of the circuit breaker what it good or bad in standard value. Another case that was estimated what the probability of arrival time for equipment's spare part with known parameters of qualitative normal distribution.Then review the confusing symbols in the above-mentioned construction design and explain in detail, so as to thoroughly understand the relationship between the parameters of the normal distribution theory. This article demonstrates writing skills with both text and pictures and operational instructions to enhance learning interest and aim to apply what you have learned.

Keywords:Normal distribution, Mean, Variation, Standard deviation, Bell-shaped curve.

1. INTRODUCTION

In view of the fact that the normal distribution law has been widely used in the industry and daily life for a long time, so that it inspires the author's inspiration, if its characteristics are applied to the evaluation of the transmission time of equipment spare parts and the judgment of the detection data of the power circuit breaker interruption time, it will be a kind of new way.So, author uses EXCEL software to compile it, so that what is being for the purpose of applying what I have learned. The order of arrangement of this article is preface, literature review, description of normal distribution theory, instructions for compiling formulas, actual case verification, review, and finally ends with conclusion.

2. LITERATURE REVIEW

First of all, select a few related articles from many historical documents, and describe the characteristics as follows. [1]The generalized normal distribution is used to discuss the relationship between the parameters and the mean, variance, skewness, and kurtosis, and the maximum likelihood method is proposed to evaluate the distribution parameters and illustrated with a real data set. [2] The new skewed normal distribution has three parameters instead of one, which can be used to increase the flexibility of random variables in life and industry.[3] A reliability data analysis method based on generalized normal distribution is proposed to meet the needs of modern aviation equipment failure prediction.[4] This paper treats the bounds on the deviation between the conditional distribution of projections and the Gaussian approximation, and explicitly expresses the key property functions of the number of projections and random vectors. [5] This paper discusses an evaluation method for actual body temperature measurement, which estimates skin temperature by Gaussian function mapping.[6],[7],[8],[9],[10],[11]documents describe the relevant laws of normal distribution and compiling instructions.[13],[14] are different from the properties of this article and are only for reference.

According to the characteristics of the above literature, the author was inspired to develop a novel detection and estimation method, writing this article "To judge the power circuit breaker interrupting time and theprediction of maintenance schedule with normal distribution probability."

3. NORMAL DISTRIBUTION

Normal distribution, also known as the bell-shaped curve, was first used by the great mathematician Gauss in 1794 to describe the small error when repeatedly measuring the same variable, so it is also called Gaussian Distribution or error curve. After 1872, it was called the normal curve by the American logician Peirce. The normal distribution is a very common and very important continuous probability distribution. The curve drawn by its probability density function is called the normal curve, and a strict proof is given by assuming that the error obeys the normal distribution. The normal curve presents a bell-shaped curve area, which is obtained from the mean and standard deviation of the random variables of the sample group, and then the relationship between them, calculated with formulas of normal distribution and to convert into a probability, which is widely used.Now introduction the normal distribution formula 1,2,3,4,5 are as follows:

$$\boldsymbol{X \sim N(\mu, \sigma^2)} \tag{1}$$

$$\boldsymbol{\mu = \sum_{i=1}^{n}(x_i)/n} \tag{2}$$

$$\boldsymbol{\sigma^2 = \sum_{i=1}^{n}(x_i - \mu)^2/n} \tag{3}$$

$$\boldsymbol{\sigma = \sqrt{\sum_{i=1}^{n}(x_i - \mu)^2/n}} \tag{4}$$

$$\boldsymbol{Z = (X - \mu)/\sigma} \tag{5}$$

where $\sigma \neq 0$.

X is a random variable that needs to be standardized.

μ is the mean value of the sample group.

$\sigma^2$is the variation of the sample group.

σ is the standard deviation of sample group.

Z is the standard score.

P is the probability of the area of the bell shape.

If σ=1, the Z value is approximately from – 3 to + 3. The area of the bell shape is 1 of the total value of the

probability, as shown in the Fig. 1below.

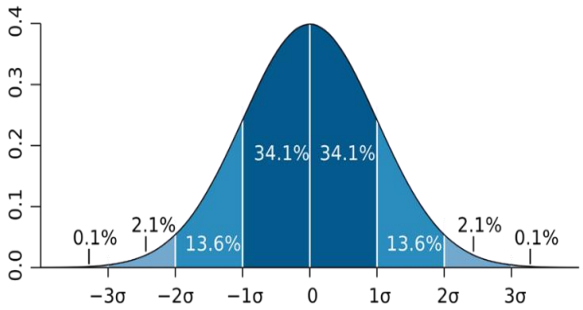


Fig 1. Bell-shaped curve [12]

So, the probability value can be converted by any value or interval within the area, apply the formula NORM.DIS(A2(data),average(data), standard deviation(data),TRUE) in the EXCEL software to accurately calculate the corresponding probability value,such as formula 6.

$$P(Z > 1)=P((X-\mu)/\sigma) \quad (6)$$

4. COMPILE AND APPLY PROGRAM

Inheriting the above theory and applying it to the actual case verification, first of all, the block flow chart, as shown in Fig. 2, reveals its operation steps, which includes EXCEL software calculation instruction terms and graphic display.

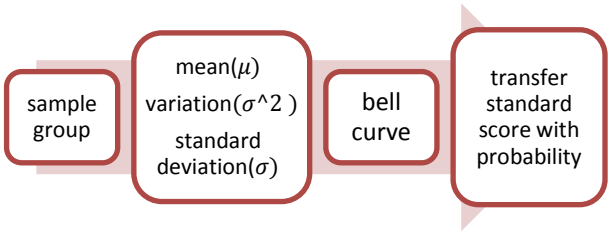


Fig 2. Constructing a normal distribution flow chart

Process steps:After establishing the sample group of random variables, find the average value (μ) from the total value of the random variables in the group, next to sum each square which is each random variable minus the average, and then divide it by the group number (n), which is called the variation (σ^2) and the square root of the variation is the standard deviation (σ),When the number of group (n) is greater than 30, the approximately normal distribution of can be established. The area of the bell-shaped curve and the position of its related parameters are shown in Fig 1. The X-axis is called the standard score from negative 3 to positive 3, and the sum of the area of the bell-shaped curve is 1, the probability of the corresponding X-axis under the bell-shaped curve can be calculated by the distribution table or by the EXCEL software program.In order to illustrate with simple data: the group of random variables, group's numbers, the average value, the number of variations, and the standard deviation, their interrelationships and algorithms. Special calculation is performed with the group number (n) being 4 and the random variables being 10, 8, 10, and 16 respectively.

Average = (10+8+10+16) /4 = 11.
Variation = ((10 – 11) ^^{2} + (8 – 11) ^^{2} + (10 – 11) ^^{2} + (16 – 11) ^^{2}) / 4 = 9.
Standard deviation = 9^$^{0.5}$ = 3.

If the EXCEL software formula algorithm is used, the instructions are as follows:In the EXCEL worksheet, first enter the data in the first column (B1) of column B, and enter the data in the second column (B2) of column B, and enter the data of 10, 8, 10, and 16 in sequence (B2), (B3), (B4), (B5), complete the number of samples of 4 random variables.Enter the average value in column 1 (C1) of column C, enter =AVERAGE(B2:B5) in (C2), and the result 11 will appear in C2.Enter the variation number in column 1 (D1) of column D, and enter =VARPA(B2:B5) in (D2), and the result 9 will appear in D2.Enter the standard deviation in column 1 (E1) of column E, enter =STDEV(B2:B5) in (E2), and the result 3 will appear in E2. The actual results of EXCEL calculation are shown in Table 1.

Table 1. The actual results of EXCEL

data	mean	variation	standard deviation
10	11	9	3
8			
10			
16			

To construct the normal distribution (bell-shaped) area, the EXCEL software formula will be used to calculate the approximate bell-shaped curve area.Then give another sample group (n) 32. The mathematics scores (random variables) of the mid-term exam of the whole class are as follows: [60.8 57.8 62.2 68.6 67.4 67.8 68.3 65.6 66.5

62.1 70.1 69.2 64.2 66.2 70.2 62.2 58.6 56.8 62.4 54.8 59.4 60.8 66.1 68.4 62.6 54.8 58.8 64.1 68.2 66.8 58.8 58.6]. As shown above, enter the mathematics grade data in the first column (B1) of column B, and enter the grades of each student in the second column (B2) to (B33) in column B to complete the sample number of 32 random variations.Then enter the average value in the first column (C1) of column C, and enter = AVERAGE (B2:B33) in (C2), and the result 63.4 will appear.Enter the variation number in the first column (D1) of column D, and enter = VARPA (B2:B33) in (D2), and the result 20.3 will appear in D2.Enter the standard deviation in the first column (E1) of column E, enter = STDEV (B2:B33) in (E2), and the result 4.6 will appear in E2.In order to establish the bell-shaped area, continue to enter the word group boundary in the first cell (F1) of column F, enter (=$C$2-3*$E$2) in F2, which is (μ-3*σ), and enter in F3 (=F2+E$2) is (F2+σ), Enter (=F3+E$2) in F4 is (F3+σ), enter (=F4+E$2) in F5 is (F4+σ), enter (=F5+E$2) in F6 is (F5+σ) , enter (=F6+E$2) in F7 is (F6+σ), enter (=F7+E$2) in F8 is (F7+σ).First integrate G1H1 into a column and enter the histogram (bell-shaped) graph, and then follow the steps in the main screen Data-Data Analysis-Histogram-OK-Create the input range of the corresponding box (drag from $B$2:$B$33) —Group boundary range (drag from $F$2:$F$8)—output $G$2—OK—OK—after the group boundary and frequency appear, highlight the area and then select Insert—in the chart—choose the appropriate graph—a bell-shaped appears, as shown in Fig 3.

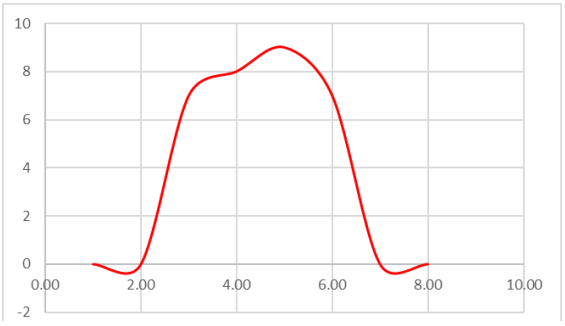


Fig 3. A bell-shaped

After the area of the normal distribution (bell-shaped) is known, the formula 7 can be used

$$\boldsymbol{Z} = (\boldsymbol{X} - \boldsymbol{\mu})/\boldsymbol{\sigma} \qquad (7)$$

Find the standard score (Z) of any random variation = $(\boldsymbol{X} - \boldsymbol{\mu})/\boldsymbol{\sigma}$ ，Z ~ N (0,1)

Enter the standard score in the first column (I1) of column I through the EXCEL software formula, and enter = (B2 - $C$3)/$E$3 in (I2), and the standard score Z value result - 0.571 will appear.

The probability,such as formula 8.

$$\text{P (a} \leq \boldsymbol{X} \leq \boldsymbol{b})\boldsymbol{P}((\boldsymbol{a} - \boldsymbol{\mu})/\boldsymbol{\sigma} \leq (\boldsymbol{X} - \boldsymbol{\mu})/\boldsymbol{\sigma} \leq (\boldsymbol{b} - \boldsymbol{\mu})/\boldsymbol{\sigma})$$

$$\boldsymbol{P}((\boldsymbol{a} - \boldsymbol{\mu})/\boldsymbol{\sigma} \leq \boldsymbol{Z} \leq (\boldsymbol{b} - \boldsymbol{\mu})/\boldsymbol{\sigma}) \qquad (8)$$

Where a and b are the smallest and largest random variation values in the sample group, respectively. The calculated group's standard score ranges from – 1.870 to + 1.478.Enter the probability in the first column (J1) of column J, and enter = NORM.DIST(B2, average, standard deviation, TRUE) in (J2), and the probability (P) result of 0.286 will appear.The range of the standard score for the sample group was verified by the above program to be between – 1.883 and + 1.484.In addition, if the probability value of any random variation is known, the value of the random variation can be obtained by the formula 9.

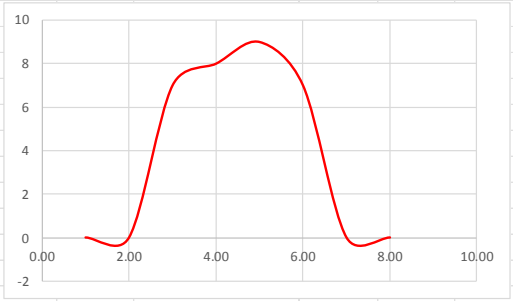
$$\boldsymbol{X} = \boldsymbol{Z}\boldsymbol{\sigma} + \boldsymbol{\mu} \qquad (9)$$

Enter the random variation value in column 1 (K1) of column K, and enter = NORM.INV (J2, mean, standard deviation) in (K2), and the result of random variation value 60.8 is consistent with the data in B2.To verify the probability P (X>= 70) or P = 1 - P (X<= 70) of the mathematics scores of the above-mentioned students in the class above 70, enter the probability value of 70 or above in the first column (L1) of the L column, and enter After inputting = 1 - NORM.DIST (70, mean, standard deviation, TRUE) in (L2), the probability of scoring above 70 is 0.076 (7.6%). However, among the actual 31 people, there are 2 people with a score of 70 or above, so the proportion is 2/31, which is equal to 0.064 (6.4%). In addition, if the probability of scores below 60 is P (X < 60), enter the probability value below 60 in the first column (M1) of column M, and enter = NORM.DIST(60, average, standard deviation) in (M2),TRUE) the probability of appearing below 60 points is 0.230 (23%).However, among the actual number of 31 people, there are 9 people with scores below 60 points, so their proportion is 9/31, which is equal to 0.290 (29%).

The verification probability data of the above two cases are very similar, so it proves that this method is feasible. The data and graphics of the above-mentioned mathematics actual worksheets for the whole class are shown in Table 2.

Table 2. Actual worksheet data and graphics

B	C	D	E	F	G	H	I	J	L	M
data	mean	variation	standard deviation	bin	bell curve		Z	P	70 over for P	60 under for P
60.8	63.4	20.3	4.6	49.69	bin	frequency	-0.571	0.286	0.076	0.230
57.8				54.27	49.88	0	-1.227	0.112		
62.2				58.84	54.44	0	-0.265	0.397		
68.6				63.41	59.01	7	1.134	0.871		
67.4				67.99	63.57	8	0.872	0.808		
67.8				72.56	68.13	9	0.959	0.831		
68.3				77.13	72.69	7	1.069	0.857		
65.6					77.26	0	0.478	0.684		
66.5					other	0	0.675	0.750		
62.1							-0.287	0.389		
70.1							1.462	0.927		
69.2							1.265	0.896		
64.2							0.172	0.569		
66.2							0.609	0.729		
70.2							1.484	0.930		
62.2							-0.265	0.397		
58.6							-1.052	0.148		
56.8							-1.446	0.076		
62.4							-0.221	0.414		
54.8							-1.883	0.031		
59.4							-0.877	0.192		
60.8							-0.571	0.286		
66.1							0.588	0.721		



5. NORMAL DISTRIBUTION APPLICATION

This paragraph will follow the above principles and rules to detect the probability of random variable measured value data values to judge whether the operation is normal or not, estimate the time required for the arrival of ordered parts, and judge whether the SF6 capacity inside the circuit breaker meets the regulations and other cases to provide evidence. Its detection operation flow chart is shown in Fig. 4.

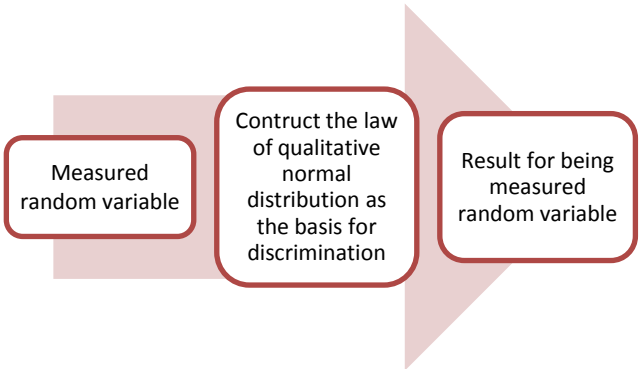


Fig 4. Detection flow chart

Firstly, collect 100 breaking time data of a certain brand of 69kV voltage level circuit breaker in the substation in the whole year, as the sample group (n), and the standard breaking time set by the manufacturer is 80ms. Then follow the above steps and use the EXCEL software formula to replace the number of random variables to 100 and the range of instructions in the formula to calculate the parameters related to the normal distribution — mean (84.5), variation (37.5), standard deviation (6.2), standard score and probability, etc., due to space limitations, only the important results and related data are extracted.

Taking two cases as examples:

Case 1, if the circuit breaker interruption calculation result of table 3 substation is different from that of table 2, only add the probability calculation command between 75ms and 90ms, and the steps are in the first column (N1) of the N column, enter the probability of 75ms to 90ms, in (N2) and enter = NORM.DIST(90, average, standard deviation, TRUE) - NORM.DIST(75, average, standard deviation,

TRUE) and the probability of occurrence is 0.750 (75.0%). It can also be said that the probability of being detected from 0.063 to 0.8112 are qualified range.Since the interval data of probability is allowable range for circuit breaker interruption as determined by the manufacturer.

Table3.Calculation results of circuit breaker interruption in substation

Item	data
mean	84.5
variation	37.5
standard deviation	6.2
probability over 90 ms	0.188
probability under 75 ms	0.063
probability in 75~90 ms	0.750

Case 2 is that the spare parts procurement time schedule is normally distributed by dispatching people from the manufacturer's warehouse to take the bus departing at 8:00 a.m. to Tainan Railway Station. The relevant parameters are N(30,20). Immediately after that, the time required to transfer from the train station to the substation by bus is normally distributed and its parameter is N(25,16). What is the probability that the spare parts will be delivered at 9:00 on time?

Let X be the time required from the manufacturer's warehouse to Tainan Railway Station, X ~ N(30,20).
Let Y be the time required to transfer from Tainan Railway Station to the substation, Y~N (25,16).
Let W be the time required from the manufacturer's warehouse to the substation W=X+Y ~ N (30+25,20+16).

Due to

$$N(55,36) = N(\boldsymbol{\mu} - \boldsymbol{\sigma^2})$$

$$Z = (60 - \mu)/\sigma = (60 - 55)/6 = 0.83$$

P (W < 60) = P (Z < 0.83) = 0.7967 = 79.6% (lookup table) or = NORM.DIST(60,55, 6,TRUE).The probability of the spare parts can be delivered at 9 o'clock on the same day is 79.6%.

Furthermore, the power circuit breaker manufacturer fills the 69kV voltage level GIS circuit breaker with GIS pressure capacity standard of 6.0 kg/cm^2, to find the probability that the pressure capacity exceeds 6.05 kg/cm^2 and the probability that the pressure capacity is less than 5.9 kg/cm^2.

- Probability of pressure capacity exceeding 6.05 kg/cm^2 = p (X> 6.05)= p ((X- μ) / σ) > ((6.05 – 6) / 0.03) = p (Z >1.66) = 1- 0.9515 = 0.0485 = 4.8%.
- Probability of pressure capacity less than 5.9 kg/cm^2= p (X< 5.9)= p (((X- μ) / σ) < ((5.9 – 6) / 0.03))= p (Z < - 3.33) = 0.0004 = 0.04%.

In this paragraph, by collecting 100 samples, the normal distribution can be established, and then the probability of a qualified circuit breaker breaking time can be calculated based on the relevant parameter data. The relevant parameter data of the qualitative normal distribution constructed by the sample data group is used to check whether the circuit breaker interruption time (also known as random variable) falls within the qualified probability range as the basis for judgment.In another case, by using two known independent qualitative normal distribution parameters.

In case 2, by using two known independent qualitative normal distribution parameters, the calculation criterion is what integrated into one is each of them the average and the variation to add. Then calculate the probability of arrival time according to the rules. The third case describes the probability that the pressure is higher than or lower than a certain pressure when the average pressure value and standard deviation are known.

The above cases are enough to prove that the normal distribution law has a wide range of applications.

6. DISSCUSION

Some easily confused formula symbols and key definitions in the article are presented as follows in this paragraph:

- To construct a qualitative sample group, the number of combinations (n) is very important, because its size maintains the bell-shaped curve of the normal distribution, so its n needs to be greater than 30 to be applicable to the normal distribution rule.
- The symbols of some related formulas involved in the normal distribution are easily confused, such as X~N (30,20) and Z = N (0,1). The former X is a random variable, ~ is approximately symbol, N is a normal distribution symbol, 30 is an average, and 20 is a variation; The latter Z is the standard score, N is the normal distribution symbol, 0 is the average(mean), and 1 is the probability of the area under the bell-shaped curve.
- According to the article, the approximately normal distribution can be constructed and used as a probability judgment tool.

7. CONCLUSION

Looking at the above theories and using EXCEL software to compile a usable detection tool, first collect sample data (n) 100 pieces of power circuit breaker interruption time data from the maintenance records.To construct the approximately normal distribution of qualitative and use the obtained relevant parameter data as the detection benchmark and then the probability of the product to be tested as qualified or not.In addition, two known normal distribution parameters—mean and standard deviation—are used to predict the probability of time course and evaluate the probability of excessive or insufficient GIS filling of equipment. It is known from the above-mentioned that this method is feasible and highly accurate, can effectively evaluate the probability of judging whether the detection data is qualified or not, and can effectively predict the probability of the time required for equipment replacement.So, it is worth promoting to practitioners in the field of electrical engineering for reference.

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