Research on Distribution System Faults Evaluation Method

Gao Hong, Wu Yaowei, Gong Wenjiang, Pan Hongkai

Fushun Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

wuyaowei568@163.com

Keywords: distribution system, faults evaluation, fuzzy theory, condition-based maintenance, weighting set

Abstract. All the factors causing distribution system faults are analyzed for improving safety and reliability of power system. Comprehensive and scientific evaluation for distribution system faults are made by fuzzy comprehensive evaluation method and the ordering is done by their severities. This method is able to monitor the distribution system safety and reliability and give reference for distribution system condition-based maintenance, thus improve the ability of distribution system safe operation.

Introduction

Distribution system fault prediction methods mainly depend on the professional knowledge and experiences and the understanding to the actual situation of operating crew currently. The fault prediction set acquired by this way and treated every fault at same incidence rate could not be perfect and accord with actual conditions [1].

According to the probability values of the factors which lead distribution system faults, the faults evaluation method based fuzzy theory has been achieved. This method can evaluate distribution system faults quantitatively by fuzzy transformation which chooses all the factors led to distribution system faults as evaluative factors and applies fuzzy transformation theory and maximum membership degree rule.

Fuzzy comprehensive evaluation theory

Fuzzy comprehensive evaluation is based on fuzzy mathematics to evaluate things quantitatively [2]. It consists of following steps.

(1) Determine the objects to be evaluated X .

(2) Set up factor set U .

Assume X has n factors which are able to influences X . Let $U=(U_1,U_2,...,U_n)$.

(3) Set up evaluating set V .

V can represent the order of evaluating result. Let V_i be the order of evaluation, m be the number of the order, $V=(V_1,V_2,...,V_m)$.

(4) Set up weighting set W .

Assume the weight of $U_1,U_2,...,U_n$ is $w_1,w_2,\cdots w_n$ separately, and $\sum_{i=1}^{n} w_i=1$. Let $W=(w_i,w_2,\cdots w_n)$.

(5) Set up comprehensive evaluating matrix R .

R is the fuzzy matrix of U and V . Let $R=(r_{ij})_{n\times m}$, and $\sum_{j=1}^{m} \mathrm{r}_{ij}=1$. r_{ij} is the quantity index of degree of u_i pertaining to v_j .

(6) Fuzzy comprehensive evaluating operation.

$$B=W\circ R=(w_1,w_2,\cdots w_n)\circ(r_{ij})=(b_1,b_2,...,b_n) \quad (1)$$

Where $b = \mathop{\vee}\limits_{j=1}^{n}(w_i \wedge r_{ij})$, $j = 1,2,...,m$. In the equation (1) b_j on the line j of B is obtained by the following measure. Firstly the elements in W is compared with the corresponding line j elements in R separately to get the minimum ones, then get the maximum of the values, finally these maximum values are normalized.

(7) The results of comprehensive evaluation are

$$V_{result} = B \cdot V \qquad (2)$$

(8) The objects evaluated are ranked according to their results of comprehensive evaluation.

Transmission line faults evaluation

The classes of condition based maintenance of the equipments in distribution system can indicate the possibility of the faults. Considering the transmission lines usually affected by severe weather, the relative probability of distribution system element faults can be determined by means of fuzzy comprehensive evaluation according the real time monitoring data.

Determine the objects to be evaluated

Choose the transmission lines in the distribution systems as the objects to be evaluated X .

Choose the evaluative factors U

Considering the reasons of distribution system faults, the classes of condition based maintenance of the equipments in normal weather and wind, ice covering, lightening, temperature and insulation pollution are adopted to be the evaluative indexes. The more value of index, the more possibility of fault happening.

(1) The classes of condition based maintenance of transmission line

The classes of condition based maintenance of transmission line can reflect the conditions in normal weather. So it can be used in fault pre   and evaluation.

(2) Wind

Transmission lines could be damaged by 6 and upper class wind (over 10.8-13.8m/s speed) [4]. The actual value of wind speed is used in the evaluating process if it is larger than 10.8m/s, otherwise is zero.

(3) Ice covering

Short circuit will happen on transmission lines since shorten electrical distance between the lines caused by ice covering and lines swaying caused by ice breaking off. Sometimes over load ice covering leads to many towers broken down, transmission line disconnection and electric power fittings spoiled [5, 6]. The measuring value of ice thick is used in the evaluating process if it is thicker than the value of design, otherwise, the value is assumed zero.

(4) Lightening

Lightening not only brings transmission line and its outdoor auxiliary equipment damages, but also causes indoor equipment damage or breaker trip. The index value takes 1 in heavy weather, or takes 0.

(5) Temperature

In the high temperature situation the overhanging of transmission line will increase, results in flashover between the line and ground or between the line and the overlapping spanning objects, simultaneously the temperature changing may make electrical load change [4].

(6) Insulation contamination

The pollution flashover will happen when the degree of insulation contamination increases to a certain extent. The value of leakage current may use for representing insulation contamination degree [7].

In summary, the classes of condition based maintenance of transmission line may indicate the possibility of faults when the latter 5 index value is not high enough to affect the transmission line in normal weather. The probability of transmission line fault is affected by the latter 5 indexes only in heavy weather.

So evaluating factor set $U = (U_1, U_2, U_3, U_4, U_5, U_6)$ is (classes of condition based maintenance, wind, ice covering, lightning, temperature, leakage current).

The fuzzy description of evaluating result factors

Set up fuzzy evaluating set $V = \{V1, V2, V3, V4, V5\}$, where $V1, V2, V3, V4, V5$ respectively is worse, bad, general, good and better.

The determination of degree of membership function

The membership function can be solved by the fuzzy statistical method [2]. The evaluating factor matrix obtained is

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & r_{n3} & r_{n4} & r_{n5} \end{bmatrix} \quad (3)$$

The determination of weight

The weight of evaluating factor of transmission line can be determined by analytic hierarchy process [8].

(1) Judgment matrix construction

Judgment matrix can be obtained according to the associated standard evaluation by comparison between every two elements [8].

$A = (a_{ij})_{n \times n}$

(2) Separate hierarchy ordering and consistency check

Proper vector W can be obtained through characteristic root achieved from the judgment matrix $(AW = \lambda W)$. After undergoing normalization, it becomes the relative important ordering sorting weight of corresponding factor in the identical hierarchy.

The characteristic root is

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{W_i} \quad (4)$$

Where the $(AW)_i$ is the i th vector of AW .

The proper vector can be obtained through the solution of following equations (5), (6), (7).

$$M_i = \prod_{j=1}^{n} a_{ij} \quad (i, j = 1,2,...,n) \quad (5)$$

$$V_i = \sqrt[n]{M_i} \quad (6)$$

$$W_i = V_i \Big/ \sum_{i=1}^{n} V_i \quad (i = 1,2,...,n) \quad (7)$$

The consistency index (CI) calculation is needed for consistency check of separate hierarchy ordering.

$$CI = (\lambda_{\max} - n)/(n-1) \quad (8)$$

Where n is the exponent number of judgment matrix.

The random consistency rate (CR) is

$$CR = CI / RI \quad (9)$$

When CR is less than 0.1, the consistency of separate hierarchy ordering is thought reasonable, or the element value of judgment matrix needs to adjust.

For different value of n , the corresponding value of RI as shown in Table 1.

Table 1 the value of RI

n	3	4	5	6	7	8	9	10	11
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The result of comprehensive evaluation

The result of comprehensive evaluation can be obtained by the product operation between the quantification of evaluating set V and the fuzzy comprehensive evaluating set B.

Case analysis

In a distribution network, 15 transmission lines are chosen for fault evaluation in one day in winter.

(1) In winter the evaluating indexes $U = (U_1, U_2, U_3, U_4, U_5, U_6)$ are classes of condition based maintenance, wind, ice covering, lightning, temperature and leakage current.

(2) The weights of above indexes are

$$A = \begin{bmatrix} 1 & 5 & 2 & 5 & 3 \\ 0.2 & 1 & 0.2 & 4 & 0.3333 \\ 0.5 & 5 & 1 & 5 & 4 \\ 0.2 & 0.25 & 0.2 & 1 & 0.3333 \\ 0.3333 & 3 & 0.25 & 3 & 1 \end{bmatrix}$$

According to formula (5), (6), (7) and (4), (8), (9), we get W = (0.4047, 0.0826, 0.3249, 0.0475, 0.1403) and λ_{max} =5.41, CI=0.1026, CR=0.09 $<$ 0.1 separately.

(3) The result of comprehensive evaluation

The ordering result of comprehensive evaluation of 15 transmission lines is as shown in Table 2.

Table 2 the ordering result of comprehensive evaluation

Serial number	Line terminal number	U_1	U_2 (m/s)	U_3(mm)	U_4 (℃)	U_5 (mA)	The result of evaluation
1	3-9	5.00	4.00	0.00	0	5	4.61
2	2-6	5.00	6.00	4.00	−2	10	4.33
3	8-9	4.70	8.30	3.00	−3	20	4.21
4	8-10	4.61	3.00	3.00	−4	29	4.00
5	4-9	4.21	8.00	4.00	−6	40	3.91
6	16-19	4.00	10.0	2.00	−9	60	3.90
7	16-17	3.90	11.00	4.00	−10	50	3.86
8	1-3	3.60	10.80	2.00	−12	30	3.71
9	12-13	4.00	13.00	4.60	−13	45	3.60
10	2-4	3.57	13.56	3.90	−12	69	3.41
11	5-10	3.90	14.00	4.21	−11	61	3.29
12	11-14	4.00	10.00	4.02	−12	90	3.29
13	11-13	4.12	10.08	6.00	−9	110	3.21
14	17-22	3.67	9.09	2.00	−10	150	3.19
15	1-5	3.99	12.01	4.00	−1	190	3.01
Weight		0.405	0.083	0.325	0.048	0.140	

The conclusion can be obtained from Table 2 that the result of line 3-9 is 4.61 and approximately belongs to worse class; the result of line 1-5 is 3.01 and belongs to general class.

Closing remarks

The faults of distribution network can be evaluated by means of evaluating the on line values of various factors to breakdown the transmission lines by method based on fuzzy theory. So the results of the evaluation are more scientific and reasonable.

References

[1] WANG Shou-xiang, ZHANG bo-ming, GUO Qi, Integrated performance index method of contingency screening in online dynamic security assessment, *Power System Technology*. 2005, 29(1): 60-64.

[2] XIE Ji-jian, LIU Cheng-ping, *Fuzzy Methods and Its Application*, HUST Press, 2006.

[3] TIAN Ling, X1NG Jian-guo, Discussion on making decision about electric equipment for condition based maintenance, *Power System Technology*. 2004, 28(16): 63-66.

[4] WANG Shou-li, *Electric Power Climate*, China Meteorological Press, 1994.

[5] FU Xian-ming, The analysis and countermeasures of transmission line icing damage, *Hubei Electric Power*. 2003, 26: 63-64.

[6] ZHANG Yu, transmission line icing online monitoring system, *High Voltage Technology*. 2008, 34(9): 1992-1995.

[7] GUAN Zhi-cheng, MAO Ying-ke, WANG Li-ming, Review on Leakage Current Characteristics of Contamination Insulators, *High Voltage Technology*. 2008, 34(1): 1-6.

[8] ZHANG Jing-fang, SUN Shi-yun, HU Ze-jiang, Method to Determine Weights of Fuzzy Evaluation for Power Supply Capability in Distribution Networks, *Journal of KUNMING University of Science and Technology(Natural Science Edition)*. 2008，33(1): 70-74.