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The Comprehensive Evaluation of Smart Distribution Grid Based on Cloud Model

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Abstract

Smart distribution grid is an important part of smart grid. Cloud model is used in smart distribution grid; It can achieve mutual combination and conversion between the qualitative evaluation system and the quantitative study. The paper introduces the development status of the smart distribution grid and distribution grid, the numerical characteristics of cloud model and algorithm of synthesized cloud. By establishing the model of two-level index synthesized cloud and remarks cloud, the evaluation results can be given in the form of probability distribution. The example shows that the model of the evaluation results is intuitive and reliable; it has important significance in guiding practice.

Keywords: smart grid； smart distribution grid；cloud model； Synthesized cloud

1. Introduction

As the basis and premise for low-carbon electricity, smart grid technology develops rapidly in many countries recent years, and promoted the smart grid vigorously. Smart gird planning in China is focused on power generation, transmission, substation, distribution, consumption, scheduling, communication and information.

National Grid continue to strengthen distribution grid structure, develop urban and rural power grid , speed up new distribution grid in rural areas and construction and transformation of key cities , increase the county level of power grid construction and transformation, strengthen and improve the distribution grid, gradually eliminate the supply "bottleneck", constantly improve supply capacity and reliability;

Distribution automation technology develop quickly and be applied to smart distribution grid, It gradually raise the level of distribution automation, distribute generation and clean energy access technology research of distribution grid obtain more significant achievement; part of the urban distribution management system including Geographic Information System (GIS), Production Management System (PMS), Outage Management System (OMS) and Work Management System (WMS), these can connect to such as Distribution Supervisory Control And Data Acquisition (DSCADA), Customer Management

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System (CMS), Enterprise Resource Planning (ERP) systems. This is the distribution grid platform with efficient processing and public support. [1-2]

2. Smart distribution grid

Smart distribution grid can improve power generation reliability, system operating efficiency and power quality of terminal devices, Contributing to distributed generation, energy storage ,micro-networks optimization of network operation and coordination, Achieving efficient interaction of demand-side management, Contributing to the integration of advanced modern management concepts, helping to integrate and optimize the operation and maintenance of distribution assets and management systems.[3]

The intelligent level of smart distribution grid depends on the construction of the following three aspects.

- The level of automation and control integration of distribution grid L.

L depends mainly on five aspects. The level of comprehensive monitoring capabilities L_1, flexible control capabilities L_2, optimize operational capability L_3, operation and maintenance management capability L_4 and self-healing capacity of feeder L_5.

- The level of distribution of information M.

The level of distribution of information depends on six aspects, the construction level of geographic information platform M_1, the construction level of intelligent auxiliary decision platform M_2, the construction level of fault management and application platform M_3, optimal equipment maintenance application platform level M_4, staff and management platform level M_5, data mining and massive processing level M_6.

- The level of distributed generation / energy storage and micro-grid access and coordination of control N.

This indicator depends on the level of PV promotion of renewable energy such as degree of N_1, electric vehicle charging station and charge pile facilities, application of N_2, diversification of energy supply complementary distribution network scheduling optimization level N_3 and large clean energy limited Scheduling strategies and methods of distribution of building a total of four degree N_4.

The future of the smart distribution grid is part of a large complex system, when we evaluate its intelligent level; there aren't proper mathematical tools to determine the exact value of some indicators in evaluation system.

To take advantage of hierarchical structure to analyze and assess systems, Expert scoring methods can express some indicators which can not be quantified in quantified form. But these quantitative indicators are no longer fuzzy, which lost the flexible features of qualitative evaluation, and also can not in conformity with the habit of natural language. Cloud model is the uncertainty convert model between concepts of a qualitative concept and its quantitative expressed in natural language. The cloud model is applied to assess the intelligent level of distribution grid, solve the problem of qualitative and quantitative conversion.

3. Cloud Model

Cloud is a quantitative and qualitative uncertainty conversion model, which was proposed by Professor Deyi Li based on the traditional fuzzy set theory and probability statistics.

A. The definition of cloud

Cloud is an uncertainty conversion model between a qualitative concept and its quantitative representation, which is expressed by natural language values. That is to say, the cloud model is an uncertainty model used to achieve the conversion between qualitative and quantitative.

Suppose U is a quantitative domain expressed by precise values, and C is a qualitative concept on the domain. If the quantitative value $x \in U$, and x is a random realization to the qualitative concept C, whose membership $\mu(x) \in [0,1]$ for C is a random number with stable tendency:

$$\mu : U \to [0,1], \forall x \in U, x \to \mu(x)$$

Then, the distribution of x on the domain is called as cloud, and each x is called as droplet [4].

B. The number features of normal cloud

Cloud is made up of many cloud droplets, and a single cloud droplet is a specific realization of the qualitative value in number. Its abscissa value represents the quantitative value corresponding to qualitative concept, and the ordinate value expresses the membership degree of the quantitative value on behalf of the qualitative concepts. The three number features of cloud are expectation E_x, entropy E_n and hyper entropy H_e [5 ~ 8].

- E_x

Expectation best representatives the value of the qualitative concept, and it is usually the x value corresponding to the gravity of cloud, reflected the center value of corresponded qualitative concept.

- E_n

Entropy represents the measure to the fuzzy degree of the qualitative concept, the size of which directly determines the number of elements that can be accepted by the qualitative concept on the domain, and also reflects the margin of qualitative value based on both this and that.

- H_e

Super entropy expresses the uncertainty measurement of entropy, and that is the entropy of entropy. The size of super entropy indirectly reflects the cloud's thickness.

The 3 E_n rules of cloud refers to that the total contribution of all elements on the domain U to the qualitative concept C is 1.That is, 99.7% of the cloud droplets will fall into the range (E_x – 3 E_n , E_x +3 E_n). Thus, cloud fell on the outside of this scope are small probability events for a qualitative linguistic values concept, and it can be ignored.

The generation algorithm of normal cloud is as follows:

- $x_i = G(E_x, E_n)$

Generating the normal random number x_i that the expectation is E_x and the variance is E_n .

- $E_{ni}' = G(E_n, H_e)$

Generating the random number E_n' that the expectation is E_n' and the variance is H_e .

- $\mu_i = \exp[-(x_i - E_x)^2 / 2E_{ni}'^2]$

Generating the cloud droplets (x_i , μ_i).

Normal cloud is the most common to express the linguistic values. Figure 1 shows the cloud (20, 5, 0.8) that the number of cloud droplets is $n = 1000$ and the language value is "about 20 kilometers".

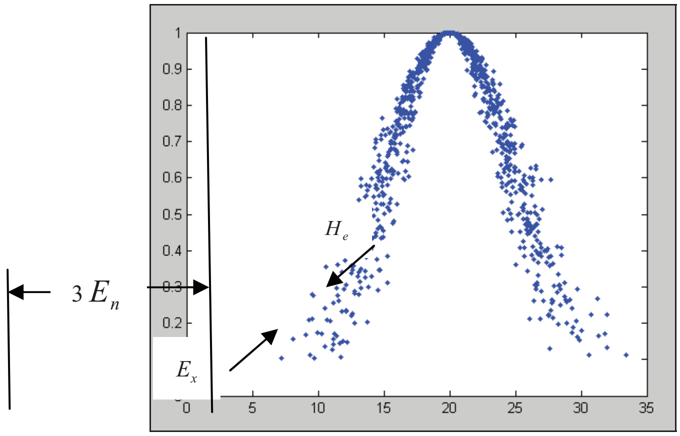

Figure 1. Cloud of abuout 20 kilometers.

C. Synthesized cloud

In data mining, concept generalization is a very important method, which often needs to abstract many concepts to higher level concepts. The synthesized cloud technology is the concept generalization of cloud theory. Synthesized cloud abstracts two clouds to one high level cloud, which means two or more same type linguistic values abstract to a higher level concept language, that is the concept generalization in data mining.

The designate basic cloud models of two languages in the domain of discourse as $C_1(E_{x_1}, E_{n_1}, H_{e_1})$ and $C_2(E_{x_2}, E_{n_2}, H_{e_2})$, the digital features of synthesized cloud which build up by two basic clouds are:

$$E_x = \frac{E_{x_1} \times E_{n_1} + E_{x_2} \times E_{n_2}}{E_{n_1} + E_{n_2}}$$

$$E_n = E_{n_1} + E_{n_2}$$

$$H_e = \frac{H_{e_1} \times E_{n_1} + H_{e_2} \times E_{n_2}}{E_{n_1} + E_{n_2}}$$

In the domain of discourse, we can extend synthesized cloud to many basic clouds of the same type.

D. Cloud Comprehensive Evaluation

The evaluation results of an object in an intended target depends on the evaluation results of the object in a series of sub-indicators, and comprehensive evaluation is the process of getting the evaluation results of objective indicators by the evaluation results of sub-indicators. Comprehensive evaluation model in the fuzzy mathematics use quantitative methods to make remarks on the sub-indicators.

With the cloud model theory, qualitative methods can be used to represent the sub-indicators on the reviews, and the reference to the comprehensive evaluation of cloud models can make decisions process more realistic [9].

The comprehensive evaluation based on cloud model includes three sets:

- $U = \{u_0, u_1, u_2 \cdots, u_m\}$

It is indicator set, u_0 is the purpose indicator, and the other are the sub-indicators;

- $V = \{v_1, v_2 \cdots, v_m\}$

It is weight set, $v_i \geq 0$ and $v_1 + v_2 + \cdots + v_m = 1$;

- $W = \{w_1, w_2 \cdots, w_m\}$

It is remarks set.

Due to remarks are always fuzzy concept, such as “good, normal and bad”, every remark can be described using one-dimensional normal clouds. Some remarks have bilateral constraint such as “better “poor” remarks, they correspond to the range of satisfaction are both upper limit and lower limit; There are also comments only unilateral constraints, such as “very good” “very poor”, they correspond to the range of satisfaction are upper limit or lower limit.

For the remark of bilateral constraint $[C_{\min}, C_{\max}]$, expectations can be used to be as the median value of constraint conditions, cloud which main function area is the bilateral constraints can be used to approximate the regional remarks; cloud parameter computation formula is as follows:

$$E_x = (C_{\min} + C_{\max})/2$$

$$E_n = (C_{\max} - C_{\min})/6$$

$$H_e = k$$

k is a constant, It can be adjusted specifically according to its fuzzy remarks.

The unilateral constraints’ remarks, for example $C_{\min}$ and $C_{\max}$,we can determine the expected value of the default boundary parameters firstly, such as remarks "very good" ,its expectations(satisfaction) is 100%, then calculate cloud parameters using above formula, and describe it with a half rise and a half drop cloud.

If there is sub-index and several II indicators, at the same time considering weight, then the integrated cloud computing will have to adjust the first three formulas to the following [10].

$$E_x = \frac{E_{x_1} \times E_{n_1} \times v_1 + E_{x_2} \times E_{n_2} \times v_2 + \cdots + E_{x_m} \times E_{n_m} \times v_m}{E_{n_1} \times v_1 + E_{n_2} \times v_2 + \cdots + E_{n_m} \times v_m}$$

$$E_n = E_{n_1} \times v_1 \times m + E_{n_2} \times v_2 \times m + \cdots + E_{n_m} \times v_m \times m$$

$$H_e = \frac{H_{e_1} \times E_{n_1} \times v_1 + H_{e_2} \times E_{n_2} \times v_2 + \cdots + H_{e_m} \times E_{n_m} \times v_m}{E_{n_1} \times v_1 + E_{n_2} \times v_2 + \cdots + E_{n_m} \times v_m}$$

4. Application example

According to the provisions of the relevant documents and reference the actual evaluation of the experience, the cloud comprehensive evaluation model can measure the current level of intelligent distribution network; Abbreviated as X (objective indicators) .The sets of indicators as follows

$$U = \{X, L, M, N\}$$

$$U_1 = \{L, L_1, L_2, L_3, L_4, L_5\}$$

$$U_2 = \{M, M_1, M_2, M_3, M_4, M_5, M_6\}$$

$$U_3 = \{N, N_1, N_2, N_3, N_4\}$$

The I indicators, II indicators and their weight distribution of X as shown in Table I.

Table I The indicators and their weight distribution of X

I indicators	weight	II indicators	weight
L	0.35	L_1	0.25
		L_2	0.2
		L_3	0.1
		L_4	0.3
		L_5	0.15
M	0.35	M_1	0.1
		M_2	0.2
		M_3	0.25
		M_4	0.2
		M_5	0.15
		M_6	0.1
N	0.3	N_1	0.35
		N_2	0.35
		N_3	0.2
		N_4	0.1

Remarks set $W = \{highest, high, medium, low\}$, remarks cloud shown in Table II.

Table II remarks cloud and the corresponding interval

remarks	cloud	the corresponding interval
highest	（100，6.6，1）	（80，100）
high	（70，3.3，1）	（60，80）
medium	（50，3.3，1）	（40，60）
low	（0，13，1）	（0，40）

According to the current development status of istribution network, combined with expert advice and assessment of the actual experience, we can create the II indicators' remarks cloud as shown in Table III.

Table III II indicators and their remarks cloud

II indicators	remarks cloud
L_1	（90，6.6，1）
L_2	（85，6.6，1）
L_3	（68，3.3，1）
L_4	（45，3.3，1）
L_5	（50，3.3，1）
M_1	（85，6.6，1）
M_2	（72，3.3，1）
M_3	（50，3.3，1）
M_4	（45，3.3，1）
M_5	（90，6.6，1）
M_6	（35，1.7，1）
N_1	（70，3.3，1）
N_2	（30，1.7，1）
N_3	（60，3.3，1）
N_4	（60，3.3，1）

According to the cloud comprehensive evaluation formula, the results are cloud L (73.66, 23.93, 1), cloud M (68, 13.79, 1), cloud N (61, 13.2, 1). This conclusion is not only the quantitative assessment of intelligent distribution network on the current level, a good conversion method between qualitative reviews and quantitative assessment, but also can guide future construction of all aspects of distribution networks.

5. Conclusion

It is proved feasible that cloud model in comprehensive assessment of the distribution network intelligence level, the actual proof is, the model also applies to all comprehensive evaluation with two or more sub-indicators.

However, the reliability evaluation result of the model depends on the selection of a series of factors, such as the entropy of each cloud model. These parameter values need assessment engineer's actual experience and through repeated research to obtain. Therefore, the comprehensive evaluation for future smart grid distribution intelligent level, how to determine the relevant parameters more reasonably and accurately is the focus of the next step.

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