2018 5th International Conference on Information Science and Control Engineering

Fault Risk Prevention Model of Distribution Network based on Hidden Markov

Diao Yinglong
China Electric Power research Institute
CEPRI
Beijing, China
diaoyinglong@126.com

Huang Renle
State Gird Beijing Electric Company
SGCC
Beijing, China
huangrenle@139.com

Wang Cunping
State Gird Beijing Electric Company
SGCC
Beijing, China
wangcunping163@163.com

Jia Dongli
China Electric Power research Institute
CEPRI
Beijing, China
jiadl@epri.sgcc.com.cn

***Abstract*—Because of the factors such as the unknown or accidental fault causes and the few factors such as the number of records before and after the distribution network fault, in view of the difficulty of the fault analysis of the distribution network, the risk prediction is inaccurate, the risk exclusion or fault isolation scheme can not be formed systematically and scientifically, so it is difficult to improve the emergency handling capacity of the distribution network. A risk control model of distribution network fault based on the non deterministic finite state machine is proposed, and the migration path of each state in the risk process of the distribution network is analyzed. The non deterministic finite state machine and the hidden Markov algorithm are combined to calculate the state transfer probability through the sample training, and the various input causes are considered comprehensively and comprehensively. In order to minimize the impact of data on the risk prediction results, a series of control schemes are formed, and the correctness of the model is verified by using a more perfect fault data set of typical distribution network in large city.**

Keywords-component; Finite-state machine; Fault Risk Prevention; Hidden Markov; Distribution Network

I. INTRODUCTION

The application of various intelligent optimization algorithms in the distribution network has solved many difficult problems, such as short-term load forecasting, equipment state assessment, energy efficiency analysis, anti electric stealing management and so on. After years of research and improvement, the accuracy and efficiency of the power distribution network have been greatly improved, which provide the corresponding information, automation and intelligentization of distribution network. The auxiliary decision-making and theoretical support is located at the production site, which strengthens the overall management level of distribution network. The fault risk prevention and control of distribution network is a typical multi factor condition, using the control method to realize multi state dynamic transfer, so as to quickly restore the normal complex problems of the system, and have the multi level and multi dependency and other nonlinear characteristics in the state migration. The target of risk prevention and control of the fault grid is to reduce the failure rate of the distribution network and continue to promote the reliable, stable and autonomous operation of the distribution network, and to take the risk of the distribution network in the control area in an all-round way. Improve the efficiency of fault handling and recovery, and further improve the operation and maintenance management level of distribution network by means of dispatching control or patrol inspection and maintenance.

But the fault of the distribution network is deteriorated from the risk to the fault, and then to the organizational repair, after the maintenance, repair and upgrading, it is unable to quickly form a feedback chain and avoid the expansion of the fault. At the same time, it is limited to the poor quality of the data in the distribution network, the absence of external data and the internal and external data channel. It is not clear that the characteristics of the inevitability factors are not obvious, the interference of the contingency factors is strong and so on, which leads to the lack of pertinence of the means of preventing and controlling the fault risk, and there is no qualitative analysis method like the economic dispatch and the power control for the time being. However, large data centers are gradually set up in various provinces and cities, and the data of various distribution networks are gradually perfected through the integration of internal and external data, data fusion of battalion distribution, and the management and migration of the ledger data, so as to realize the holography and closed loop of the distribution network data, making the risk prevention and control of the fault gradually becoming possible.

At present, most of the research points of fault risk prevention and control in distribution network are pre control, that is, to carry out reliability evaluation and N-1 setting in the stage of network frame construction and planning, and build model from the structure of distribution network as

978-1-5386-5500-9/18/$31.00 ©2018 IEEE
DOI 10.1109/ICISCE.2018.00231

IEEE computer society

input, but in fact, it can not accurately reflect the risk of randomness, dynamics and process in the running state. Paper [1] presents a fast assessment method of power outage risk in DG distribution network based on Equipment random failure. Latin hypercube sampling technology is introduced into the sampling phase of system state, which can achieve islanding control quickly and accurately. Paper [2] uses accident tree analysis and analytic hierarchy process to establish a set of objective, practical and applicable power system security risk assessment system. Based on historical experience data, decision tree, fuzzy mathematics and other methods are applied to adjust the power grid planning, operation and maintenance resources, operation and maintenance plan. Paper [3] establishes a multi-year monthly failure statistical model for transmission lines, and puts forward the method of analyzing the maintenance risk of transmission lines based on the expectation of the expected shortage of electricity supply by meteorological factors, and proposes the scheme of line inspection and equipment maintenance based on the results. However, in view of the increasing complexity of the distribution network frame, the load especially the distributed characteristics are varied, the updating and running mode of the grid are changing frequently. The collection data is difficult to describe the real running state of the distribution network, or the fault risk prevention and control means can not be quickly and accurately feedback. It is necessary to abstract the operation characteristics of the distribution network into a multi state and multi state. The complex model of the path can make the operation risk of distribution network suit the remedy to the case.

II. HIDDEN MARKOV MODEL

Hidden Markov model (HMM) is a statistical model, it is used to describe a Markov process with hidden unknown parameters. The difficulty is to determine the implicit parameters of the process from observable parameters. Then we use these parameters for further analysis, such as pattern recognition. Hidden Markov model is a kind of Markov chain, its state can not be observed directly, but it can be observed by observation vector sequence, each observation vector is expressed as various states through some probability density distribution, each observation vector is produced by a state sequence with the corresponding probability density distribution. Therefore, the hidden Markov model is a double stochastic process, which has hidden Markov chains with a certain number of States and displayed random function sets. The following diagram is a state transfer graph of a hidden Markov model with three states, in which X represents an implicit causal state, Y represents an observable output, a represents the state transition probability, and B represents the output probability.

In order to drive the transfer between states in hidden Markov models, we need the following assumptions:

$$P(X_i \mid X_{i-1} ... X_1) = P(X_i \mid X_{i-1}) \tag{1}$$

$$P(X_{i+1} \mid X_i) = P(X_{j+1} \mid X_j) \tag{2}$$

$$P(Y_i ... Y_T \mid X_1 ... X_T) = \prod P(Y_i \mid X_t) \tag{3}$$

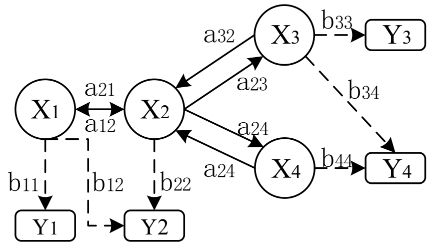

Figure 1. State transfer graph of hidden Markov model

The formula (1) is a first order independent state hypothesis, that is, the X_i state is only independent of the X_{i-1} state, which is only the function of X_{i-1},the conditional probability distribution of the past state, and formula (1) is the basic hypothesis of all Markoff class analysis including its variants. Formula (2) is a time independent hypothesis. For all time sections i and j, the state is independent of the specific time. Formula (3) is output independence assumption. Output Y_i is only related to X_i, and output is only related to the current state.

From the above assumption, we can build hidden Markov models five tuples:

$$HMM\{N, M, \pi, A, B\} \tag{4}$$

In which N represents the number of hidden states, M represents the number of observable states, π_n is the initial state probability, and $A = \{a_{ij}\}$ is the probability transfer matrix of the hidden state, and $B = \{b_{ij}\}$ represents the probability relation matrix between the hidden state and the output state, which is called confusion matrix, for example, the hidden Markov model shown in Figure 1 can be expressed as:

$$Y \overbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ b_{12} & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & b_{34} & b_{44} \end{bmatrix}}^{X} \tag{5}$$

There are three main applications of HMM: (1) the probability of finding a given output sequence is known by HMM model. (2) the best hidden state sequence is known as output state sequence. (3) we constructed HMM models with known output and hidden state sequence sets.

III. ANALYSIS OF FAULT PREVENTION AND CONTROL IN DISTRIBUTION NETWORK

At present, the fault data of distribution network are derived from distribution automation system, power use information collection system, power quality on-line monitoring system, production management system, distribution repair platform and so on. The fault of distribution network is only second level from the deterioration of the risk to the generation fault, and the distribution automation action and the group weave force repair feedback often come from the minute to number. The time scale is different, and the problem is that it is difficult to find out the cause of the fault and can not respond quickly. Therefore, it is necessary to carry out the fault state transfer and fault prevention and control analysis.

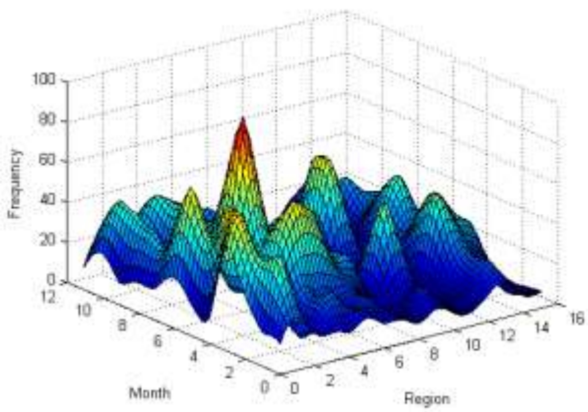

Figure 2. Distribution network fault distribution trend in a certain area

Figure 2 shows the distribution trend of distribution network in a certain area, the plane coordinate is the month and the fault area, the vertical coordinate is the frequency of fault occurrence. It can be found that the fault has 2~3 wave peak change in one year, and the general change law of the region is more consistent. As shown in Figure 3 as the failure repair process of distribution network, it can be seen from the diagram that in the control system of fault risk of distribution network, it is necessary to send the repair team to the site to carry out the fault analysis, which greatly reduces the efficiency of the fault repair, so it is adopted according to the distribution network. The analysis of inter state migration is of high application value for targeted prevention and control of distribution network failures.

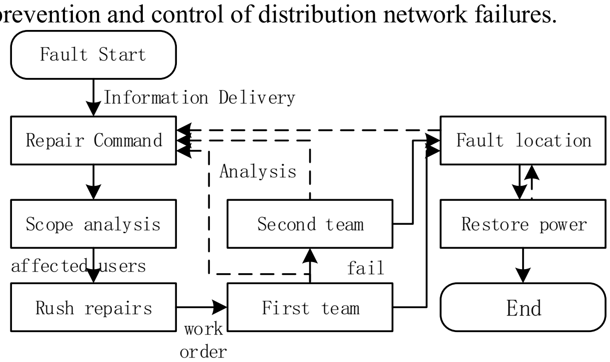

Figure 3. Failure repair process of distribution network

IV. FAULT PREVENTION AND CONTROL ANALYSIS METHOD BASED ON HMM

In view of the uncertain dynamic system composed of multi class fault representation in distribution network, the migration path of each state in the risk process of distribution network is analyzed. The fault prevention and control analysis model of distribution network based on the implicit Markov method is established by combining the non deterministic finite state machine with the hidden Markov algorithm. According to the observed state of different characterization in the fault process of distribution network, the observable explicit fault characterization output sequence set is set up, the hidden Markov model is constructed, and then based on the HMM model, the state sequence is characterized in the distribution network failure process, and a most likely fault cause is found.

The process of fault risk prevention and control method of distribution network can be divided into three parts: (1) by sorting out the fault events, the fault characterization and the hidden reasons of the field core are summarized, and the initialized display fault state sequence set, the hidden fault cause sequence set are formed, and the hidden Markov five elements are initialized according to the two sets. Group. (2) to initialize the other variables in the hidden Markov five tuple based on forward backward algorithm, by defining the pretest probability and the posterior probability of two variables, based on the forward backward learning method, the hidden Markov parameters are constantly updated to find the condition probability of the output state under the hidden state, and the recursion is until the maximum, hidden Markov. The model is built. (3) based on the hidden Markov model, we input the state sequence of the display and characterization of a given fault, extract all the state sequences, determine the maximum probability and path of each state, and then get the most possible cause of failure in the reverse order. (4) setting up the fault prevention and control plan library, using the method of combining the scene with the pre case library, constantly renewing the prevention and control methods for the reasons of different faults in the pre case library. If the fault causes are discovered in the process of rush repair, the HMM parameters are updated and the model iterative reconstruction is realized. Through the analysis of hidden Markov fault prevention and control analysis method, the reason is analyzed in the first time according to the first time sequence of the observable fault state, so as to achieve the purpose of quick feedback and accurate repair.

A. Indue of fault representation and hidden reasons

The network structure of the distribution network is complex, the type of equipment is uneven, the power of operation and maintenance inspection is weak, the characteristics of the fault are not obvious under the micro weather micro terrain and the micro condition. It is difficult to diagnose and locate the fault in a long time. By combing and statistics of the fault causes of distribution network in many areas, external force destruction is the first major fault, followed by user influence, natural cause, equipment cause and other unknown situation. The external factors are divided into foreign causes, reasons, tree line traffic and bird. The natural factors are divided into the cause of lightning strike and the reason of icing. The equipment factors include insulator failure, fall type fuse failure, switch fault on column, lightning arrester malfunction, knife and gate fault and cable head and so on, most of the fault equipment are tight, batch quality, aging and so on. User impact factors include theft, user equipment damage, equipment line design defects and so on. As shown in Table 1,

TABLE I. TABLE TYPE STYLES

Type of Fault	Details
External force destruction	Foreign body causes, reasons, tree line traffic and bird...
User impact	Theft, user equipment damage, equipment wiring design defects…
Natural causes	The cause of the lightning strike and the reason for the ice cover.
Equipment cause	The equipment factors include insulator failure, drop fuse fault, on column switch fault, lightning arrester fault, knife and gate failure and cable intermediate head etc.
Other unknown	…

Although the fault features of the distribution network are not obvious, the hidden faults can be excavated from the relay protection action, the switch action of distribution automation, the acquisition of analog and signal quantity, the user feedback, the fault indicator display and so on.

B. The construction of hidden Markov model

The construction of hidden Markov model is a model training process. For the given state of the observable fault feature, the local optimal of the hidden Markov model can be obtained based on the forward backward algorithm. For the hidden Markov model five tuples $HMM\{N, M, \pi, A, B\}$:

$$P(Y \mid X) = \sum_{i=1}^{N} P(Y_i \mid X) = \sum_{i=1}^{N} a_{ti} b_{ti} \tag{6}$$

The positive auxiliary variable $\gamma(X_t, X_{t+1})$ is defined as the failure probability of t time and t+1 time.

$$\gamma(X_t, X_{t+1}) = P(P(X_t = x_i), P(X_{t+1} = x_j)) \tag{7}$$

$$\gamma(X_t, X_{t+1}) = \frac{a_{ti} ai_j b_{t+1,j} b_{j,t+1}}{\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ti} a_{ij} b_{t+1,j} b_{j,t+1}} \tag{8}$$

A reverse auxiliary variable is defined. Given the Y observable sequence and HMM five tuple, the $P(X_t = x)$ probabilities of t time are:

$$\varphi(X_t) = P(P(X_t = x_i)) \tag{9}$$

$$\varphi(X_t) = \frac{a_{ti} b_{ti}}{\sum_{i=1}^{N} a_{ti} b_{ti}} \tag{10}$$

$$\varphi(X_t) = \sum_{t=1}^{N} \gamma(X_t, X_{t+1}) \tag{11}$$

Then, according to the parameter learning process in the forward backward algorithm, we constantly update the values in HMM five tuples, making $P(Y \mid X)$ the largest. That is to calculate the expected value of $\varphi(X_t)$ and $\gamma(X_t, X_{t+1})$, iterative computation (12) - (14), and constantly update HMM five tuple parameters.

$$S = \varphi(X_t) \tag{12}$$

$$a_{ij} = \frac{\sum_{t=1}^{T-1} \gamma(X_t = x_i)}{\sum_{t=1}^{T-1} \varphi(X_t = x_i)} \tag{13}$$

$$b_{jk} = \frac{\sum_{t=1}^{T} \gamma(X_t = x_j)}{\sum_{t=1}^{T} \varphi(X_t = x_j)} \tag{14}$$

C. Quick recommendation of fault risk prevention and control strategy

In view of the causes of fault hiding, based on the field verification, the HMM model and the pre case library are constantly updated to achieve accurate and rapid feedback and accurate repair.

V. EXAMPLE ANALYSIS

In order to verify the correctness of the risk prevention and control model based on Hidden Markov chain, the data of one year's fault event, measurement collection and risk data are selected. The prediction result of 3355 failure events is as follows, the algorithm accuracy rate is 82.6%.

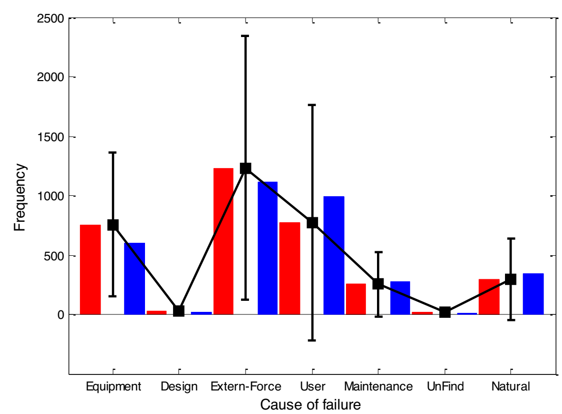

Figure 4. rediction results and errors

VI. SUMMARY

In this paper, a fault risk prevention and control model of distribution network based on Hidden Markov chain is proposed, which combines the multiple states of the distribution network risk generation, fault occurrence and prevention and control plan to form a state machine model. The state sequence of the fault events can be observed by the hidden Markov chain analysis, and the cause of the hidden fault is excavated. Through a year's failure data analysis and verification of a large city, it is proved that the method is of high value and feasibility.

ACKNOWLEDGMENT

This paper is supported by State Grid Corporation of China Research Program: Distribution network big data analysis technical study and platform development for supporting lean management. (52020116000G). And, The National Key Research and Development Program of China (Basic Research Class 2017YFB0903000)-Basic Theories and Methods of Analysis and Control of the Cyber Physical Systems for Power Grid.

REFERENCES

[1] Z. Quan, L. Jingshu, L. Ruijin, et al. Fast Assessment of Power Failure Risk in Distribution Network Containing Distributed Generation[J], Power System Technology, 2014,38(04):882-887.

[2] W. Bo, Y. Dahai, Y. Xianggen, et al. A Security Risk Assessment System of Complicated Power Grid Based on Multiple Factor Analysis[J]. Power System Technology, 2014,38(04):882-887.

[3] Z. Quan, L. Jingshu, Liao Ruijin, et al. Rapid assessment of power system blackout risk with distributed generation [J]. Power System Technology, 2014, (04): 882-887.

[4] X. weite, L. zongxiang, Q. ying, et al. A Risk Warning Method for Urban Distribution Network Based on Associated Recognition of Typical Fault and Environment Scenario[J]. Power System Technology, 2017, 41(08): 2577-2584.

[5] C. Baoqing, H. Fengqin, G. Zhonghua. Application of wavelet transform based grey theory to fault forecasting of hydroelectric generating sets [J]. Power System Technology, 2005(13):40-44.

[6] W. Wenke, W. Fushuan, X. Yusheng, et al. Prediction of chain failure of power system based on markov chain [J]. Automation of Electric Power Systems, 2013, 37(05):29-37.

[7] L. Huizhou ."Application of Data Mining Technique in Customer Relationship Management". International Journal of Systems and Control, vol. 02, pp. 104-109,2006.

[8] Y. Zhao, Q. Xie, L. Yun. "Comparsion analysis of data mining models applied to clinical research in Traditional Chinese Medicine. Journal of Traditional Chinese Medicine", vol. 02, pp. 627-634,2014.

[9] "Distributed anonymous data perturbation method for privacy-preserving data mining". Journal of Zhejiang University(Science A:An International Applied Physics & Engineering Journal), vol. 02, pp. 952-963,2009.

[10] Yunfei Yin. "Air-combat behavior data mining based on truncation method". Journal of Systems Engineering and Electronics, vol. 02, pp. 827-834,2010.