ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2012. No. 7(123)
ELEKTRONIKA IR ELEKTROTECHNIKA

AUTOMATION, ROBOTICS
AUTOMATIZAVIMAS, ROBOTECHNIKA

An Effective Fault Identification Technique for Electrical Engineering

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crossref http://dx.doi.org/10.5755/j01.eee.123.7.2370

Nomenclature

The notation used throughout the paper is stated below:

Ω_k	population;
$p(j \mid x)$	conditional probability;
q_k	prior probability;
$p_k(x)$	probability density function;
x	observation sample;
μ_j	mean vector;
Σ_j	covariance matrix;
$p(k \mid x)$	posterior probability;
Y_k	discriminant function.

Introduction

The voltage and current synchronized phase data of electric power system under the current operation status can be real-time provided by the wide area measurement system (WAMS)/ Phasor measurement unit (PMU) [1, 2]. The wide area protection scheme constituted with synchronized phasor mainly adopts the centralized decision. Based upon the electric quantity change, the centralized decision master station utilizes the voltage and current information provided by all PMU equipments at the same time to determine the fault elements, then puts the main focus on backup protection related to the fault elements, and establishes the tripping strategy [3-5]. However this type of multi-information wide area relay protection scheme requires the whole information of concentrated power grid, and mainly depends on wide area synchronized measurement system. It requires large quantity of information and high quality synchronism. Nowadays the ratio of PMU placement in power grid is still relatively low, and PMU itself has problem regarding the dynamic accuracy. Most of fault localization algorithms for synchronized phasor are affected by the parameter errors of the system dramatically. The regional current differential protection is increasingly influenced by situations such as TA saturation after information increase, capacitive current distribution and load current cross. Therefore the wide area protection that utilizes the information from PMU measurement is restricted by low reliability, heavy burden of communication and operation and inappropriate match of the hardware condition.

Most of the wide area protection schemes are currently facing one problem and that is the disconnection between theoretical research and practical application. Fault localization scheme that utilizes logic quantity multi-information is an effective way to fundamentally improve backup protection capability and possesses potential practicality. Fused information is usually the decision resulted under different kinds of operation characteristics made by directional protection, distance protection, overcurrent protection, low voltage protection and other protections. To realize wide area backup protection scheme, it uses the relevance, complementarity and consistency between different protection principles from different protection stations relating to fault point as bases, and uses the expert system, genetic algorithm, rough set and other information fusion algorithms as platform, and also aims to accurately locate fault element and to acquire adequate fault-tolerant ability [6,7]. It has characteristics such as simple implementation, no requirement for accurate synchronization, accurate fault localization and fast, and it can overcome the many weaknesses of traditional backup protection.

The core of wide area protection is accurate identification of faults [8–11]. In practice, an ideal measurement way to the protection, monitoring and control of the whole power system is provided by the PMUs and WAMS. In our researches, the nodal voltage phasor $\dot{V}$ and the branch current phasor $\dot{I}$ from the PMUs globally deployed in the power system are the basic variables. Considering the information missing of the information transmission in WAMS system, we will provide an effective fault identification technique for electrical engineering based on different kinds of failures.

The paper is organized as follows. In Section 2, the classification criteria of multiple populations are presented. In Section 3, the effective fault identification based on different kinds of failures in electrical engineering is discussed carefully. Finally, the paper is concluded in Section 4.

The classification criteria of multiple populations

In the study of multiple populations, Bayesian discrimination not only considers to construct discriminant, but also calculates conditional probability $p(j \mid x)(j = 1,2,\cdots,k)$ that new samples belong to each population. After comparing these conditional probability, the new samples will be fallen under the population with maximal conditional probability [12–14].

For k populations $\Omega_1,\Omega_2,\cdots,\Omega_k$, their prior probability is respectively $q_1,q_2,\cdots,q_k$, and their probability density functions are $p_1(x), p_2(x),\cdots, p_k(x)$. x is an observation sample, the posterior probability of sample x belongs to the kth population is

$$p(j \mid x) = \frac{q_j p_j(x)}{\sum_{i=1}^{k} q_i p_i(x)}, \; where \;\; j = 1,2,\cdots,k \quad (1)$$

and if $p(j \mid x) = \max_{1\le j\le k} p(j \mid x)$, one can determine that sample x comes from the jth population.

If k populations $\Omega_1,\Omega_2,\cdots,\Omega_k$ obey p-dimensional normal distribution, and the probability density function can be expressed as

$$p_j(x) = \frac{1}{\sqrt{(2\pi)^p \left|\Sigma_j\right|}} \times \\ \times \exp[-\frac{1}{2}(x-\mu_j)'\Sigma_j^{-1}(x-\mu_j)], \quad (2)$$

where μ_j and Σ_j are respectively mean vector and covariance matrix. During the course of Bayesian discrimination, one needs find out the biggest one from $q_j p_j(x)$. In order to simplify discriminant function expression, one can take logarithm and get

$$\ln[q_j p_j(x)] = \ln q_j - \frac{1}{2}\ln(2\pi)^p - \\ -\frac{1}{2}\ln\left|\Sigma_j\right| - \frac{1}{2}x'\Sigma_j^{-1}x - \frac{1}{2}\mu_j'\Sigma_j^{-1}\mu_j + x'\Sigma_j^{-1}\mu_j. \quad (3)$$

Furthermore, let

$$Z(j \mid x) = \ln q_j - \frac{1}{2}\ln\left|\Sigma_j\right| - \\ -\frac{1}{2}(x-\mu_j)'\Sigma_j^{-1}(x-\mu_j). \quad (4)$$

Because $Z(g \mid x)$ contains the covariance matrix of k population, in practical calculation, one can further assume

$$\Sigma_1 = \Sigma_2 = \cdots = \Sigma_k = \Sigma. \quad (5)$$

Then the discriminant function can be expressed as

$$Y(j \mid x) = \ln q_j - \frac{1}{2}\mu_j'\Sigma^{-1}\mu_j + x'\Sigma^{-1}\mu_j \quad (6)$$

or

$$\begin{cases} Y_1 = \ln q_1 + c_{01} + c_{11}x_1 + c_{21}x_2 + \cdots + c_{p1}x_p, \\ Y_2 = \ln q_2 + c_{02} + c_{12}x_1 + c_{22}x_2 + \cdots + c_{p2}x_p, \\ \vdots \qquad\qquad \vdots \\ Y_k = \ln q_k + c_{0k} + c_{1k}x_1 + c_{2k}x_2 + \cdots + c_{pk}x_p. \end{cases} \quad (7)$$

In the classification process, one can complete classification mainly based on $Y(j \mid x)$, but it is not the posterior probability $p(j \mid x)$, in fact

$$p(j \mid x) = \frac{q_j p_j(x)}{\sum_{i=1}^{k} q_j p_j(x)} = \\ = \frac{\exp[Y(j \mid x)]\cdot\exp[\delta(x)]}{\sum_{i=1}^{k}\exp[Y(j \mid x)]\cdot\exp[\delta(x)]} = \\ = \frac{\exp[Y(j \mid x)]}{\sum_{i=1}^{k}\exp[Y(j \mid x)]}, \quad (8)$$

wherein $\delta(x)$ has no relevance to j, and $\ln[q_j p_j(x)] = Y(j \mid x) + \delta(x)$. In other words, the j which maximizes Bayesian discriminant function is just corresponding to maximum posterior probability. So, one can compare those posterior probability and determine the populations that observation samples should belong to.

Fault identification based on different kinds of failures in electrical engineering

The fault identification technique presented in this paper utilizes the fundamental components (phasors) of the voltages and currents measured by WAMS/PMU. And the data acquisition mode can be consulted reference [6,7]. According to different kinds of failures: single line-to-ground (SLG), line to line (LL) (AB, BC, CA), double line-to-ground (DLG) (AB, BC, CA), three-phase (AB, BC, CA), we have carried out massive simulation experiments, and the simulation results have demonstrated that the fault identification technique in this paper is reliable. Let us take 10-machine 39-bus New-England Power System as an illustration, Fig. 1 is its electric diagram. In the structure of electricity grid, BUS-18 occurs single-phase grounding fault. By BPA simulation and program calculation with MATLAB, the vector value of corresponding variables is exported only one times in each period. And in this simulation experiment, there is serious scarcity of wide area information, eight nodes Bus8, Bus12, Bus17, Bus19, Bus22, Bus28, Bus32 and Bus34 are missing. Using these actual measurement data of corresponding variables, we will carry through fault identification about fault component and non-fault component (fault section and non-fault section).

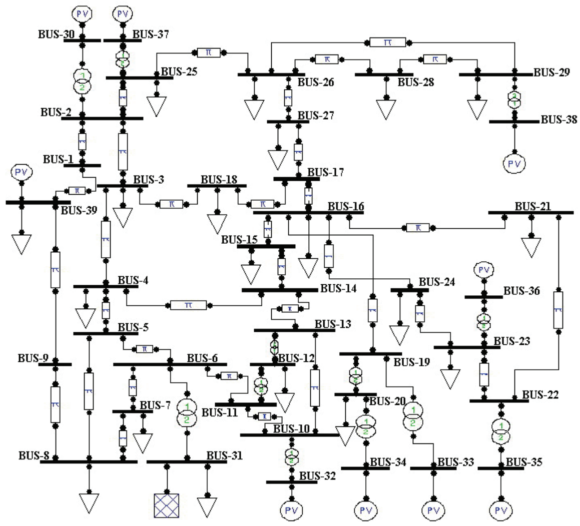

Fig. 1. Electric diagram of IEEE 39-bus system

Table 1. The posterior probability and classification of single-phase grounding fault

Node	Classification	Posterior probability (Fault population)	Posterior probability (Normal population)	Classification (Identification)
BUS-1	Normal node	0.00000	1.00000	Normal node
BUS-2	Normal node	0.00000	1.00000	Normal node
BUS-3	Normal node	0.02352	0.97648	Normal node
BUS-4	Normal node	0.00000	1.00000	Normal node
BUS-5	Normal node	0.00000	1.00000	Normal node
BUS-6	Normal node	0.00000	1.00000	Normal node
BUS-7	Normal node	0.00000	1.00000	Normal node
BUS-9	Normal node	0.00000	1.00000	Normal node
BUS-10	Normal node	0.00000	1.00000	Normal node
BUS-11	Normal node	0.00000	1.00000	Normal node
BUS-13	Normal node	0.00000	1.00000	Normal node
BUS-14	Normal node	0.00000	1.00000	Normal node
BUS-15	Normal node	0.00000	1.00000	Normal node
BUS-16	Normal node	0.00001	0.99999	Normal node
BUS-18	Fault node	1.00000	0.00000	Fault node
BUS-20	Normal node	0.00000	1.00000	Normal node
BUS-21	Normal node	0.00000	1.00000	Normal node
BUS-23	Normal node	0.00000	1.00000	Normal node
BUS-24	Normal node	0.00000	1.00000	Normal node
BUS-25	Normal node	0.00000	1.00000	Normal node
BUS-26	Normal node	0.00001	0.99999	Normal node
BUS-27	Normal node	0.00367	0.99633	Normal node
BUS-29	Normal node	0.00000	1.00000	Normal node
BUS-30	Normal node	0.00000	1.00000	Normal node
BUS-31	Normal node	0.00000	1.00000	Normal node
BUS-33	Normal node	0.00000	1.00000	Normal node
BUS-35	Normal node	0.00000	1.00000	Normal node
BUS-36	Normal node	0.00000	1.00000	Normal node
BUS-37	Normal node	0.00000	1.00000	Normal node
BUS-38	Normal node	0.00000	1.00000	Normal node
BUS-39	Normal node	0.00000	1.00000	Normal node

According to the classification criteria of multiple populations, the results of posterior probability and classification have been listed in Table 1.

From the results in Table 1, the accuracy of fault identification is 100%. Even if there is serious scarcity of wide area information, the system fault can still be accurately identified.

Conclusions

Wide area intelligent control such as self-adaptive adjustment fixed value of backup protection needs to locate fault element and fault section before backup protection action, but the traditional methods cannot fulfill this requirement. This paper provides methods for fault element localization and section definition based on classification criteria of multiple populations. By using the classification criteria of multiple populations to process the real time electric quantity information of power grid provided by WAMS, it could realize accurate fault identification.

In the study of this paper, according to different kinds of failures, even if there is serious scarcity of wide area information, massive simulation experiments have demonstrated that the fault identification technique in this paper is effective. In addition, in view of the fault occurs on a transmission line, one can still compare the size of corresponding posterior probability and identify the fault position. And the fault identification technique is also successful.

Acknowledgements

The authors thank Prof. Darius Andriukaitis and the referees for their helpful comments and suggestions. This research was supported partly by the NSFC (50837002), the Specialized Research Fund for the Doctoral Program of Higher Education (20110036110003), the Fundamental Research Funds for the Central Universities (11MG37) and the Natural Science Foundation of Hebei Province.

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Received 2011 12 09
Accepted after revision 2012 02 10

Yagang Zhang, Zengping Wang, Shuqiang Zhao. An Effective Fault Identification Technique for Electrical Engineering // Electronics and Electrical Engineering. – Kaunas: Technologija, 2012. – No. 7(123). – P. 27–30.

Wide area adaptive backup protection needs to locate fault element and fault section before backup protection action, and prepare for modifying fixed value of backup protection. The fault localization that works for wide area adaptive backup protection is the precondition of adaptive backup protection. Recently, numerous experts and scholars have done extensive studies on power grid alarm processing and fault diagnosis, however all of these methods utilized action information from protection or circuit breaker that is fulfilled after protection action. In this paper, according to different kinds of failures, we will study an effective fault identification technique for electrical engineering. Ill. 1, bibl. 14, tabl. 1 (in English; abstracts in English and Lithuanian).

Yagang Zhang, Zengping Wang, Shuqiang Zhao. Efektyvus elektrotechnikos gedimų identifikavimo metodas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 7(123). – P. 27–30.

Plačios zonos rezervuotai apsaugai užtikrinti prieš ją įjungiant reikia nustatyti sugedusį elementą ir gedimo sekciją. Gedimų lokalizavimas veikiantis plačioje adaptyvios rezervuotos apsaugos zonoje, yra viena iš adaptyvios rezervuotos apsaugos sąlygų. Neseniai nemaža ekspertų ir mokslininkų atliko intensyvius elektros tinklų avarijų valdymo ir gedimų diagnostikos tyrimus, tačiau visi siūlomi metodai remiasi apsaugos veiksmo informacija arba grandinės nutraukimu. Atsižvelgiant į įvairius gedimų tipus, analizuojamas efektyvus elektrotechnikos gedimų identifikavimo metodas. Il. 1, bibl. 14, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).