Grounding fault line selection by EMD and LSSVM

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Abstract. According to the characteristics of transient zero sequence components as well as the existing information fusion technology has the disadvantage of high sample dimension and computer overhead in fault line selection in small current grounding fault . First of all, by using the empirical mode decomposition (EMD) and the Fast Fu Liye transform (FFT) on the zero sequence signal fault feature extraction. And then through the information gain degree to calculate the weight of the line selection method. The sample data of each method separately using the simplex method (SM) to optimize the parameters of least squares support vector machine (LSSVM) integrated line selection, weight and the line fault value. Through the system simulation, the results show that the proposed method has very high accuracy and sensitivity ,which is applied to the fault line.

Introduction

Small current grounding mode is the main form of operation mode of neutral point of distribution network in china. Under the operation of single phase to ground fault in distribution network fault accounted for about 70%~80%, so when the single-phase grounding fault happens , selecting the fault line quickly and accurately is very important.

In order to improve the accuracy of line selection, domestic and foreign scholars put forward many methods for single phase to ground fault line selection, which is mainly divided into 3 categories: fault line selection method of steady state signal, fault line selection method of transient signal and information fusion . Fault line selection method of steady state signal has great limitations, which due to the neutral point grounding mode and the influence of grounding fault types .

The fault line selection method for transient signal obtained the widespread attention of domestic and foreign experts. Because of the development of signal time-frequency analysis tool, and the transient signal contains abundant fault information.

In recent years, due to the continuous development of information fusion technology, the various methods of integration has become a hot line selection. Evidence fusion, rough set, fuzzy neural information fusion technology has been applied in the fault line, and has achieved a certain effect. However, because the information fusion technology requires a large number of samples for pre training, resulting in the sample with high dimension, computer overhead, and lower convergence. At the same time, because of the diversity of types of single-phase grounding fault in small current grounding system (including: steady state, arc ,the intermittent arc, etc.) so that it is very important to the effective integration of a variety of information to improve the accuracy of line selection. In this regard, this paper presents a method of model fault line selection based on SM-LSSVM and information gain degree and verified.

Based on supporting vector machine and information gain degree model

Least squares support vector machine (LSSVM) is the standard supporting vector machine algorithm. The method use least square linear system to replace the standard method using two programming as the loss function. Assuming linearly separable data setting is (x_i, y_i) , $i = 1, 2 \cdots, M$, $x \in R^n$;class symbol $y \in \{-1,1\}$.On the basis of structural risk minimization principle, solving the optimization problem of LSSVM.

$$\begin{cases} \min \phi(\omega, e) = \frac{1}{2}\omega^T \omega + \frac{1}{2} C \sum_{i=1}^{M} e_i^2 \\ s.t\ y_i\left(\omega^T g(x_i) + b\right) = 1 - e_i \quad i = 1, 2 \cdots, N \end{cases} \tag{1}$$

In the formula, ω as the weight vector; e_k for the relaxation coefficient; c as boundary coefficient; b as the deviation; $g(x_i)$ as for the mapping function. The introduction of the Lagrange multiplier, the type (1) is transformed into unconstrained objective function:

$$Q(\omega, b, \alpha, e) = \phi(\omega, e) - \sum_{i=1}^{M} \alpha_i \left\{ y_i\left(\omega^T g(x_i) + b\right) - 1 + e_i \right\} \tag{2}$$

Each variable of type (2) respectively in the derivative, the derivative equal to zero and the elimination of variables and obtain the dual problem of linear system:

$$\begin{bmatrix} \Omega & Y \\ Y^T & 0 \end{bmatrix} \begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} I \\ 0 \end{pmatrix} \tag{3}$$

In the formula:

$I = (1, \cdots, 1)^T$, $Y = (y_1, \cdots, y_M)^T$, $\Omega_{ij} = y_i y_j K(x_j, x_k)$, $j, k = 1, \cdots, M$, $K(x_j, x_k)$;

as Kernel function satisfying the Mercer conditions. By solving the classification decision function:in the formula, σ as a plus of controlling radius, reflecting the characteristics of the data clusters.

Assuming X as a sample data set, A as the set of attributes selection method, Among them $A = \{P_1, P_2, \cdots P_m\}$, Fault and non fault line is divided into two categories, then $X = \{X_1, X_2\}$, The number of samples for the class i is $|X_i|$, the total sample number in the X is $|X|$.If a sample belongs to the class i of probability is $P(X_i)$,then

$$P(X_i) = |X_i| / |X| \tag{4}$$

At this time, the extent of uncertain information for X means transmitting message is $M(X)$.

$$M(X) = \sum_{i=1}^{m} \left(-P(X_i) \log_2 P(X_i)\right) \tag{5}$$

If you choose a fault line selection method P,assuming method P has character of $p_1, p_2, \cdots, p_j$,in the case of $P = p_j$,the number of class i is C_{ij}.In the case of $P = p_j$,the total number is Y_i.Then the probability p is

$$P(X_i \mid P = p_j) = C_{ij} / |Y_i| \tag{6}$$

On the basis of type (7) can be calculated by the method p of sample data on the conditional entropy is

$$M(X, P = p_j) = \sum_j \left(-P(X_i \mid P = p_j) \log_2 P(X_i \mid P = p_j)\right) \tag{7}$$

Then the classification of information entropy is

$$B(X, P) = \sum_j \left(P(X_i \mid P = p_j) M(X, P = p_j)\right) \tag{8}$$

The p method for the amount of information provided by the accuracy of fault line selection means the information gain degree is

$$\begin{aligned} \Delta Q_P &= M(X) - B(X, P) \\ &= M(X) - \sum_j \left(P(X_i \mid P = p_j) M(X, P = p_j)\right) \end{aligned} \tag{9}$$

The normalization of information gain degree is the weights selection method (10).

$$X = \frac{\Delta Q_P}{\sum \Delta Q_P} \tag{10}$$

By type (10) to determine the weight of each method.

The integrated line selection based on supporting vector machine and the small current grounding fault information gain degree

In small current grounding system, when the single phase to ground fault occurs, mainly on the basis of steady state signal and transient signal method to judge the fault line. In order to achieve integration of multi criterion of fault information ,the establishment of fault measure by measuring the degree of fault lines (11).

$$x_{nP}(k) = x_{rP}(k)\, x_{aP}(k) \tag{11}$$

For the steady component using FFT to extract the fault feature, because the signal characteristics of the non fault line and fault line steady method is obviously different. The relative measurement of fault and fault measurement can be easy to set up, and in the literature has a large number of analysis, which will be not repeated them. In small current grounding system, single phase to ground fault occurring, the transient fault contained rich information. In addition ,transient information is not affected by the grounding mode. So the transient fault information has a certain advantage. But the extraction of transient fault and transformation to sign degree scale have certain limitations. At present, mainly through the wavelet packet feature extraction fault transient component of energy established relevant measure function, but the function is not easy to select the wavelet packet. Therefore, this paper uses a new time-frequency tool of empirical mode decomposition (EMD) to extract transient energy.

The main idea of EMD is to use EMD to decompose the signal into a finite IMF (fixed mode function) and one residual component,and the specific method through the minimal continuous signal value and the maximum envelope line connection means, the original signal is decomposed into

$$x(t) = \sum_{i=1}^{M} IMF_{N} \tag{12}$$

Should meet two conditions: one is the decomposition of the time series, extreme point and zero crossing number equal to or a difference of 1; two is at any given moment, on the time axis signal locally symmetric

Through EMD dividing the frequency components of the signal decomposition of the order into from high to low. From the frequency domain, layers of filtration performance from high to low frequency. In small current grounding system, need to be transient component within the band, so only need to select the appropriate band IMF analysis. .

The experimental analysis

In this paper, setting up a 7 110kv/35kv distribution network feeder system model,. The parameters are as follows: feeder, the overhead lines, the positive sequence of resistance, inductance, the positive sequence admittance to ground zero, zero sequence resistance, the inductance, zero sequence admittance to ground, line length, as shown in figure 4. The L1~L7 line length were 1km, 1.5km, 2km, 1.5km, 3km, 5km, 10km.

In order to verify the validation of the method in this paper, setting the example . The 7 line’s closing angle in 10% the single-phase grounding fault through .The methods of fault line selection using SM-LSSVM to select the fault line, the reactive power method and zero sequence admittance amplitude method to vote. Table 1 gives the results of line selection, from the table 1 we can see when in the line 3 occurred in 50% closing angle happens to the single-phase grounding fault through ,then the fault line low weight is 0.4459, and the non fault line weight is high, which is due to the transition resistance, and closing angle caused by small cycle after fault transient component is short and the content is small, the steady-state amplitude is small, so the conditions of line selection is bad.

Table 1 The result statistics of part line detection

Fault line	Target Line	Fault angle/ angle，Transition resistance / Ω，Fault distance	Selection results	
			Fault weight	Selection results
1	1	0，5000，10%	0.9420	correct
2	2	45，0.5，90%	0.8206	correct
3	3	45，5000，50%	0.4459	correct
	2		-0.1022	correct
	6		-0.2797	correct
7	7	90，50，10%	1	correct
	6		-1	correct

Conclusion

This paper presents a method of fault line selection in small current based on SM-LSSVM and information gain degree. To verify the correctness of fault line selection methods based on this simulation model, and draws the following conclusion.The use of EMD to the transient component is divided into a number of IMF, each IMF represents a different frequency, and different frequency band by establishing energy entropy.To optimize the parameters of the LSSVM by using the simplex method, which avoiding the large amount of calculation, overhead long time , and has fast convergence and high precision.The method of using SM-LSSVM to reduce the dimension of fault line selection, data processing, so that the number of samples are smaller, while the SVM is suitable for processing small sample data, so it is reasonable.

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