

Phase Selection Method of High Voltage Transmission Line Fault based on Voltage Fault Component

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Abstract

In order to quickly and accurately identify the fault types of high-voltage transmission lines, a phase selection method for high-voltage transmission lines based on voltage fault components is proposed. Calculate the energy sum of each phase voltage fault component and zero sequence voltage fault component, and use the fault phase selection criterion to select the fault phase, so as to realize the judgment of the fault type of the high-voltage transmission line. Through a large number of simulation experiments, it can be known that the algorithm proposed in this paper can quickly and accurately select the fault phase, and can accurately identify the specific fault type under different fault initial angles, different transition resistances and different fault distances.

Keywords

Voltage fault component; Zero sequence voltage fault component; High-voltage transmission line; Fault phase selection.

1. Introduction

Fault phase selection is an important part of the correct operation of high-voltage transmission line relay protection. New transient protection and traveling wave protection require fast and accurate fault phase selection for transmission line faults. With the continuous construction of digital substations, phase selection components must not only provide automatic reclosing services, but also provide correct sampling data necessary for protection components. Fast and accurate fault phase selection is also a prerequisite for accurate fault location. Therefore, fast Accurate fault phase selection directly affects the safety and economy of power system operation, and is of great significance to the study of fault phase selection for high-voltage transmission lines [1-5].

At present, domestic and foreign scholars' research on the method of fault phase selection for transmission lines is mainly based on power frequency quantities and transient quantities. The traditional method of phase selection for high-voltage transmission line faults based on power frequency quantities [6-8] is susceptible to the influence of transition resistance, and the phase selection method requires a long data window, which cannot meet the requirements of today's ultra-high-speed protection. Literature [9] proposed a fault phase selection method based on the characteristics of phase-to-phase resistance change, which uses the characteristic that the measured resistance between the non-faulty phases changes slowly and the faulty phase is abrupt at the moment of the fault to identify the faulty phase. Literature [10] proposed a fault phase selection method based on line power loss increment, which uses the power loss increment of the faulted phase to be much larger than the non-fault phase to identify the faulty phase, and at the same time uses the zero sequence current auxiliary criterion to determine whether the fault is grounded. Literature [11] uses power frequency voltage to perform fault phase selection, and distinguishes single-phase grounding faults and two-phase grounding faults by comparing the voltage phase angle relationship, but this algorithm cannot identify

non-grounding faults, and the algorithm takes a long time to select phases. The fault phase selection method based on transient quantity mainly deals with the fault information contained in the transient component at the time of the fault, so as to realize the identification of the fault phase. Literature [12] proposed to use wavelet analysis to extract the initial value of the transient DC component in the fault information to distinguish the fault phase. Literature [13] proposed a fault phase selection method using EMD to extract attenuated DC components. Literature [14] first performs wavelet transformation on each mode current after three-phase current phase-to-mode conversion, and then obtains the maximum value of each mode current component on different scales, and finally uses corresponding criteria to achieve fault phase selection, but phase selection the criterion is more complicated.

In order to overcome the shortcomings of the traditional high-voltage transmission line fault phase selection algorithm, this paper proposes a transmission line fault phase selection method based on voltage fault component. By calculating the energy sum of the voltage fault components of each phase and the zero sequence voltage fault components, the fault phase selection is realized by the fault phase selection criterion. A large number of simulation results show that the proposed algorithm can accurately identify fault phases under various working conditions.

2. Voltage Fault Component

Fig.1 shows a 500kV high-voltage transmission line. The transmission line is composed of three faulty branches AB, AC and BD. The protection device TR is installed on the AB branch near the bus A. When a fault occurs at the AB branch F_1 , A, B, C The phase voltage fault components are respectively denoted as $\Delta u_\alpha (\alpha=a,b,c)$; the zero sequence voltage fault components are the sum of the three-phase voltage fault components of A, B, and C, denoted as Δu_0 .



Fig 1. 500kV high voltage transmission line

3. The Energy Sum of the Voltage Fault Component of the Transmission Line

This paper uses the voltage fault component sampling point data within a time window of 2ms (20 sampling points) after the fault to perform the corresponding calculations. The discrete time sequence of A, B, C three-phase voltage fault components and zero sequence voltage fault components is $I_\beta(l) (\beta=a,b,c,0)$, among them, $l=1,2,\dots,20$. Suppose the sum of the energy of the three-phase voltage fault component and the sum of the energy of the zero-sequence voltage fault component are respectively E_β , the calculation formula is as follows:

$$E_\beta = \sum_{l=1}^{20} \Delta u_\beta^2 \quad (1)$$

4. Fault Phase Selection Algorithm

The transmission line fault types selected in this paper are single-phase ground fault (AG, BG, CG), phase-to-phase fault (AB, AC, BC), two-phase ground fault (ABG, ACG, BCG) and three-

phase fault (ABC).), a total of 10 categories, the specific fault identification process is shown in Fig.2.

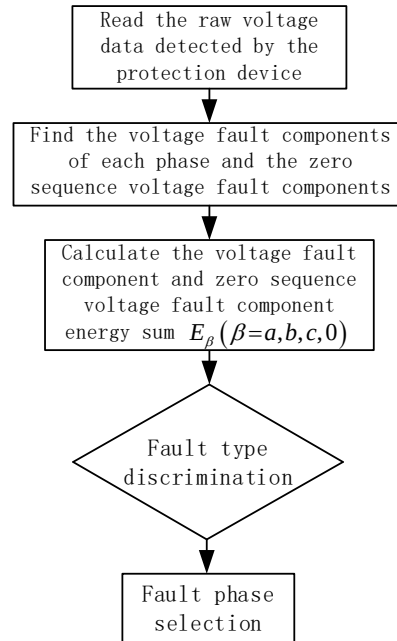


Fig 2. Fault phase selection process

The selection criteria are:

- (1) When $E_a > E_{th}$ & $E_0 > E_{th0}$ and $E_b < E_{th}$ & $E_c < E_{th}$, the fault type is phase A ground fault.
- (2) When $E_b > E_{th}$ & $E_0 > E_{th0}$ and $E_a < E_{th}$ & $E_c < E_{th}$, the fault type is phase B ground fault.
- (3) When $E_c > E_{th}$ & $E_0 > E_{th0}$ and $E_a < E_{th}$ & $E_b < E_{th}$, the fault type is phase C ground fault.
- (4) When $E_a > E_{th}$ & $E_b > E_{th}$ and $E_c < E_{th}$ & $E_0 < E_{th0}$, the fault type is AB phase to phase fault.
- (5) When $E_a > E_{th}$ & $E_c > E_{th}$ and $E_b < E_{th}$ & $E_0 < E_{th0}$, the fault type is AC phase to phase fault.
- (6) When $E_b > E_{th}$ & $E_c > E_{th}$ and $E_a < E_{th}$ & $E_0 < E_{th0}$, the fault type is BC phase to phase fault.
- (7) When $E_a > E_{th}$ & $E_b > E_{th}$ & $E_0 > E_{th0}$ and $E_c < E_{th}$, the fault type is AB phase ground fault.
- (8) When $E_a > E_{th}$ & $E_c > E_{th}$ & $E_0 > E_{th0}$ and $E_b < E_{th}$, the fault type is AC phase ground fault.
- (9) When $E_b > E_{th}$ & $E_c > E_{th}$ & $E_0 > E_{th0}$ and $E_a < E_{th}$, the fault type is BC phase ground fault.
- (10) When $E_a > E_{th}$ & $E_b > E_{th}$ & $E_c > E_{th}$ and $E_0 < E_{th0}$, the fault type is ABC phase fault.

Among them, E_{th} is the discrimination threshold of the energy sum of the three-phase voltage fault components of A, B and C, and E_{th0} is the energy and discrimination threshold of the zero sequence voltage fault component. In this paper, $E_{th}=110000$ and $E_{th0}=1$ are selected as the threshold.

5. Simulation and Testing

Use PSCAD/EMTDC electromagnetic transient simulation software to establish a 500kV high-voltage transmission line fault simulation model shown in Figure 1. The line model adopts a frequency-related distributed parameter model that can accurately reflect the transient and harmonic response. The line type uses TOWER: 3H5 towers. The transmission line configuration is shown in Fig.3, and the transmission line parameters are shown in Table 1. The bus stray capacitance is set to $C_m=0.01\mu F$. The simulation sampling frequency is 10kHz, and the length of each branch is AB=200km, AC=170km, and BD=150km.

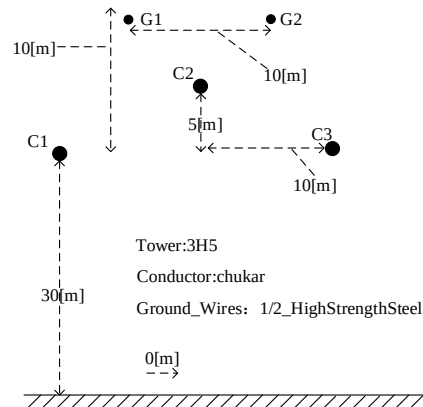


Fig 3. Transmission line configuration

Table 1.

Type of the Line	Parameter	numerical value
Phase line	Wire radius/m	0.0203454
	DC Resistor/(Ω /km)	0.03206
Ground wire	Wire radius/m	0.0055245
	DC Resistor/(Ω /km)	2.8645

Table 2. The specific conditions of the initial angle of different faults

Fault type	Fault initial angle/degree	Fault distance to point A/km	Transition resistance/ Ω
AG	25	60	100
	90		
	5		
BG	5	40	400
	60		
	25		
CG	45	70	300
	120		
	90		
AB	60	400	200
	100		
	5		
ABG	25	80	400
	60		
	45		
AC	90	90	100
	45		
	60		
ACG	120	130	200
	60		
	90		
BC	100	65	300
	45		
	25		
BCG	120	120	500
	5		
	100		
ABC	25	135	50
	90		
	5		

5.1. Algorithm Simulation Analysis

In order to verify the accuracy of the algorithm for fault phase selection under different working conditions, the algorithm was simulated and analyzed under different initial fault angles, different transition resistances and different fault distances.

5.1.1. Test Analysis of Initial Angles of Different Faults

Three groups of faults with different initial angles are simulated for 10 types of faults. The specific fault conditions are shown in Table 2, and the simulation results correspond to Table 3.

Table 3. Simulation results of different fault initial angles

Fault type	E_a	E_b	E_c	E_0	Recognition result
AG	764148	68257.08	22170.1	1392005	AG
	720446.1	113796.8	43511.92	1656838	AG
	438677.4	26057.06	9560.162	701453.2	AG
BG	9462.169	284683.4	68673.67	646693.8	BG
	7631.307	70276.86	33073.99	197611.2	BG
	9056.129	213780.5	69225.82	548722.4	BG
CG	10325.85	7065.232	152080.5	200683.5	CG
	72785.87	15711.23	384086.4	820971.3	CG
	41028.36	13411.69	327646.5	599377	CG
AB	1295141	1136341	13990.01	3.71E-22	AB
	329265.3	311678.9	2514.354	1.70E-21	AB
	1273656	1073225	17448.79	4.30E-22	AB
ABG	1469093	1399590	22891.64	10239.32	ABG
	1353658	932077.5	9936.911	50969.51	ABG
	1655026	1322277	16584.64	15831.8	ABG
AC	1341947	20341	1550053	1.12E-18	AC
	678768.4	12238.41	824114.3	2.07E-17	AC
	979969.5	17035.87	1177438	1.17E-17	AC
ACG	826631.3	12794.15	1411652	99461.79	ACG
	1393678	31549.32	905786.1	143434.7	ACG
	1383606	23783.15	1448166	9865.707	ACG
BC	9762.858	801111.6	671626.4	5.39E-17	BC
	1515.741	222334.7	210373.2	7.70E-17	BC
	6118.667	608725.4	545217.3	5.45E-17	BC
BCG	7257.573	116330.8	145591.2	135530.8	BCG
	22533.69	1072790	1232164	42129.08	BCG
	10441.66	1313280	900581.4	39492.24	BCG
ABC	1246092	1599826	141075.5	5.37E-23	ABC
	1488177	117236.9	1391711	9.03E-23	ABC
	649559.2	1866231	460941.4	5.77E-23	ABC

It can be seen from the above table that the proposed algorithm can accurately identify the specific fault type of the transmission line when different fault initial angle faults occur on the transmission line, so the proposed algorithm is not affected by the fault initial angle.

5.1.2. Test Analysis of Different Fault Transition Resistance

Three groups of faults with different transition resistances are simulated for 10 types of faults. The specific conditions of the faults are shown in Table 4, and the simulation results correspond to Table 5.

Table 4. The specific conditions of different fault transition resistance faults

Fault type	Transition resistance/ Ω	Fault distance to point A/km	Fault initial angle/degree
AG	200	120	45
	400		
	50		
BG	50	150	120
	300		
	200		
CG	100	130	60
	400		
	50		
AB	300	50	25
	500		
	100		
ABG	100	160	100
	300		
	50		
AC	200	140	25
	400		
	50		
ACG	50	80	45
	300		
	100		
BC	200	130	90
	500		
	50		
BCG	100	90	45
	300		
	50		
ABC	200	70	60
	400		
	100		

Table 5. Simulation results of different transition resistance faults

Fault type	E_a	E_b	E_c	E_0	Recognition result
AG	1169403	124040.3	36819.98	2306612	AG
	352861.4	56162.38	12248.17	679730.9	AG
	523403.6	71418.01	16034.94	1018018	AG
BG	14099.62	356947	13925.28	498284.9	BG
	12429.62	182142.9	7142.663	219282.6	BG
	12408.63	133956.5	5282.382	146261.9	BG
CG	14207.32	10240.64	297840.7	413962.5	CG
	5636.685	11071.93	112955.8	118859.9	CG
	18345.34	10954.9	387825.3	565409.4	CG
AB	1811017	1512783	20537.81	3.54E-18	AB
	1811017	1512783	20537.81	2.37E-19	AB
	1811017	1512783	20537.81	3.09E-18	AB
ABG	777123.7	133225.2	40901.99	1106698	ABG
	371663	163474.5	5480.445	102818	ABG
	638782	122699.6	26412.26	704435.6	ABG
AC	260212.2	5352.192	325616.4	2.39E-17	AC
	260212.2	5352.192	325616.4	2.97E-17	AC
	260212.2	5352.192	325616.4	6.47E-19	AC
ACG	1545518	60289.06	319255.4	873409	ACG
	942319.2	21849.81	669254.6	81626.34	ACG
	1354945	46789.41	404070.2	556846.9	ACG
BC	6539.145	427266.6	346813.9	2.26E-17	BC
	6539.145	427266.6	346813.9	1.27E-16	BC
	6539.145	427266.6	346813.9	6.22E-19	BC
BCG	40232.77	692414	242135.5	1372734	BCG
	25659.35	556512.7	199275.6	877257.5	BCG
	8283.162	366742.4	168433.3	269982	BCG
ABC	2183912	661863.7	656250.4	4.80E-23	ABC
	2183912	661863.7	656250.4	4.11E-23	ABC
	2183912	661863.7	656250.4	4.26E-23	ABC

It can be seen from the above table that when different transition resistance faults occur on the transmission line, the proposed algorithm can accurately identify the specific fault type of the transmission line, so the proposed algorithm is not affected by the transition resistance.

5.1.3. Test Analysis of Different Fault Distances

Three groups of faults with different fault distances are simulated for 10 types of faults. The specific conditions of the faults are shown in Table 6, and the simulation results correspond to Table 7.

Table 6. Details of faults at different fault distances

Fault type	Fault distance to point A/km	Fault initial angle/degree	Transition resistance/ Ω
AG	80	60	300
	160		
	40		
BG	70	45	500
	130		
	90		
CG	30	90	200
	100		
	120		
AB	90	45	100
	180		
	75		
ABG	20	120	200
	120		
	60		
AC	50	120	300
	110		
	80		
ACG	30	25	400
	160		
	50		
BC	90	60	100
	170		
	20		
BCG	40	90	200
	150		
	65		
ABC	50	120	300
	180		
	10		

Table 7. Simulation results of different fault distances

Fault type	E_a	E_b	E_c	E_0	Recognition result
AG	440646.4	79655.48	11139.99	950052.6	AG
	377341.3	71757.47	15353.34	816438.5	AG
	388232.2	64361.91	15661.02	792134.8	AG
BG	11232.82	128314.1	17968.85	258715.1	BG
	7693.603	123974.3	12937.32	170647.8	BG
	3349.581	105026.7	6024.118	105205.5	BG
CG	63534.75	19298.79	571663.4	1096187	CG
	50445.3	15540.21	456787.8	841931.5	CG
	48404.05	12136.51	444926.7	793956	CG
AB	1462690	1274135	19140.06	2.75E-19	AB
	1468225	1274496	19130.7	3.07E-19	AB
	1389431	1196799	19145.03	1.16E-19	AB
ABG	151632	241758.2	23126.13	600253.6	ABG
	192169.6	240540.6	18714.93	524780	ABG
	145793.9	219837.5	18690.99	483812.9	ABG
AC	1213321	15874.86	1360305	8.46E-18	AC
	1078277	15871.41	1215405	7.56E-18	AC
	1030740	15871.95	1194127	6.65E-18	AC
ACG	687675.9	19744.57	341800.9	193314.2	ACG
	587979.7	19870.98	272404.5	184340.3	ACG
	461602.9	17711.72	178485.9	159424.3	ACG
BC	822.2762	137059.1	122684.5	9.28E-17	BC
	821.9097	115867.3	103884.7	8.83E-17	BC
	823.0398	74259.91	65105.47	7.64E-17	BC
BCG	34893.98	317532.9	925311.9	431946.2	BCG
	32037.63	229727.2	795189	405483	BCG
	29116	168628.2	694351.4	349976.7	BCG
ABC	667123.5	1001437	2979713	2.09E-23	ABC
	679401.2	674228.4	2223452	9.98E-24	ABC
	667555.3	577361.4	2056546	9.90E-24	ABC

It can be seen from the above table that the proposed algorithm can accurately identify the specific fault type of the transmission line when faults with different fault distances occur on the transmission line, so the proposed algorithm is not affected by the fault distance.

6. Conclusion

This paper proposes a fault phase selection method for high-voltage transmission lines based on voltage fault components. By obtaining the three-phase voltage fault components and zero-sequence voltage fault components, the sampling point data energy of 2ms after the fault is obtained and the fault type is judged. The principle is simple, and the data window used is short. Through a large number of simulation experiments, the feasibility of the proposed fault phase

selection algorithm is verified. The simulation results show that it can be accurate under different fault initial angles, different transition resistances and different fault distances. Identify the specific fault type.

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